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APPRAISAL OF GRANULAR CARBON CONTACTING. PHASE III. ENGINEERING DESIGN AND COST ESTIMATE OF GRANULAR CARBON TERTIARY WASTE WATER TREATMENT PLANT

A. E. Cover, et al

Swindell-Dressler Company
Pittsburgh, Pennsylvania

May 1969

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APPRAISAL OF GRANULAR CARBON CONTACTING

PHASE III
ENGINEERING DESIGN
AND COST ESTIMATE OF GRANULAR CARBON TERTIARY WASTE WATER TREATMENT PLANT

ADVANCED WASTE TREATMENT RESEARCH LABORATORY- XII

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The engineering design and cost estimate of a 10 million-gallon-per-day plant for tertiary treatment of waste water with granular activated carbon contains the process description, design bases, plant operation, control rationale, equipment list, equipment specifications and cost estimate. This design incorporates reliability, economy and current state-of-the-art technology. Although not fully proven in practice, it is based upon the application of mature engineering judgement to available data and offers economies over any other plant which has been successfully demonstrated. (Carstea - USGS)

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APPRAISAL OF GRANULAR CARBON CONTACTING

PHASE III

ENGINEERING DESIGN AND COST ESTIMATE

of

GRANULAR CARBON TERTIARY WASTE WATER TREATMENT PLANT

for

The Advanced Waste Treatment Research Laboratory

Robert A. Taft Water Research Center

This report, the third phase of a three phase program, is submitted in fullfillment of Contract No. 14-12-105 between the Federal Water Pollution Control Administration and the Swindell-Dressler Company, a Division of Pullman Incorporated.

U. S. Department of Interior

Federal Water Pollution Control Administration

Cincinnati, Ohio

May, 1969

FOREWORD

In its assigned function as the Nation's principal natural resource agency, the United States Department of the Interior bears a special obligation to ensure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity and security of America -- now and in the future.

This series of reports has been established to present the results of intramural and contract research studies carried out under the guidance of the technical staff of the FWPCA Robert A. Taft Water Research Center for the purpose of developing new or improved wastewater treatment methods, included is work conducted under cooperative and contractual agreements with Federal, state, and local agencies, research institutions, and industrial organizations. The reports are published essentially as submitted by the investigators. The ideas and conclusions presented are, therefore, those of the investigators and not necessarily those of the FWPCA.

The total resources of Pullman Incorporated were made available for the execution of this program. The third phase, included herein, was primarily the responsibility of the Swindell-Dressler Division with support provided by the M. W. Kellogg Division. Principal engineering staff members involved included A. E. Cover, G. F. Johnson and E. V. Rymer. Coordination and participation were provided by J. F. Skelly, Project Director, and C. D. Wood, Project Manager. Phase I, "Evaluation of the Literature on the Use of Granular Activated Carbon for Tertiary Waste Water Treatment, and Phase II, "Economic Effect of Design Variables," are published as Report No. TWRC-11.

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ABSTRACT

The engineering design and cost estimate of a 10 million-gallon-per-day plant for tertiary treatment of waste water with granular activated carbon contains the process description, design bases, plant operation, control rationale, equipment list, equipment specifications and cost estimate. This design incorporates reliability, economy and current state-of-the-art technology. Although not fully proven in practice, it is based upon the application of mature engineering judgement to available data and offers economies over any other plant which has been successfully demonstrated.

INTRODUCTION

by

A. E. Cover, the M. W. Kellogg Company

and

C. D. Wood, the Swindell-Dressler Company

During the Fall of 1967, representatives of the contractor visited facilities in the United States which utilized granular activated carbon to remove undesirable persistent contaminants from waste water and/or from potable water. The purpose of the visits was to review design and operating data, secure other useful data for further evaluation and to determine the nature of any operational problems that were peculiar to specific installations.

The limited number of facilities using carbon adsorption, their size, and the short history of operating data for each, dictate that all of these installations be considered pilot plants.

Certain similarities and dissimilarities in the design and operation of the various installations are worthy of note:

Similarities

1. All carbon used was manufactured by the same supplier.

2. All regeneration furnaces were obtained from the same vendor.

3. Eductors were used for the hydraulic transport of carbon.

4. Screw conveyors were used to convey carbon, from a temporary storage tank to the inlet of the regeneration furnace.

Use of the same vendors equipment or the same supplier's carbon is not intended to imply that they are necessarily the best source.

Dissimilarities

1. Hydraulic application rate of water on the carbon beds varied from 1 gpm/ft^2 to 7 gpm/ft^2.

2. Empty bed residence time for carbon contacting varied from 18 minutes to 41 minutes.

3. The physical, chemical and biological characteristics of the water to be treated by carbon adsorption differed at each site due to the non-homogeneity of the pollutants to be removed and due to the varying types and degrees of pretreatment provided prior to carbon adsorption.

Dissimilarities (continued)

4. The goal of carbon adsorption varied by site, ranging from providing up to 90% removal of refractory organic contaminants to reducing the concentration of the organics contained in the effluent to below a fixed level.

5. Carbon regeneration frequency.

6. The use of steam in the regeneration system.

The result of the collection and evaluation of the data on carbon adsorption has been the preparation of three reports: "Evaluation of the Literature on the Use of Granular Carbon for Tertiary Waste Water Treatment," "Economic Effect of Design Variables" and the present report on the design and cost estimate of a 10-million-gallon-per-day facility.

Listed below are the design techniques and operational problems that should be improved or overcome:

1. At all facilities, carbon regeneration was a two-step discontinuous operation consisting of transferring the spent carbon from the adsorption vessel to a day tank (temporary storage) and then feeding the regeneration furnace from this tank. The capacity of the day tank varied from a day's supply of carbon for the furnace to an amount equal to the total quantity of carbon to be extracted from an adsorption vessel for regeneration.

2. All regeneration furnaces were used on an infrequent basis and for relatively short periods of time.

3. Most facilities used a screw classifier (screw conveyor) or a combination of a rotary valve and a screw classifier to regulate and transport the flow of spent carbon from the day tank to the furnace. Problems associated with the use of this equipment were affected by the nature of the waste material adsorbed on the carbon and the moisture content of the carbon. At one installation, the screw classifier required frequent replacement. At another installation, bridging of the carbon across the outlet at the bottom of the conical section of the day tank necessitated the manual use of long poles to dislodge the carbon.

4. The advantages of using steam in the regeneration of carbon is not under consideration in this report; however, the inability to use steam because of the lack of pretreatment of boiler feed water is of immediate concern. Two extremes were noted where electric steam generators were used: at one installation, agressive feed water eroded the electrodes: at another installation, the hard water rapidly fouled the electrodes of the steam generator with the deposition of chemical precipitates.

5. Epoxy coating of the interior of adsorption vessels does not provide adequate corrosion protection to the metal wall of the vessels. Pitting has occurred on the interior surfaces of adsorbers at both Lake Tahoe and Pomona.

This report contains a reliable and dependable design for a 10 million-gallon-per-day granular carbon tertiary treatment facility. All equipment selected is commercially available and has demonstrated proven reliability in such engineering areas as petro-chemicals, mining, iron and steel, water and waste, or pulp and paper.

PROCESS DESCRIPTION

The carbon adsorption process shown on process the flow diagram (Figure 1, Appendix C) was developed to provide tertiary treatment for 10 million gallons per day of waste water discharged from a secondary treatment plant (activated sludge).

Waste water flows from the final clarifier of the secondary treatment plant into a surge tank with a flow rate varying between 3500 gpm and 10,500 gpm. The surge tank functions as a leveling device to supply waste water to the carbon adsorption system at a continuous rate of 7150 gpm.

Waste water is withdrawn from the surge tank and is delivered at a flow rate of 3575 gpm to each of two adsorber tanks. These tanks, hereafter referred to as "lead" adsorbers, are each followed in the circuit by one adsorber tank referred to as the "guard" adsorber. The effluent from the latter two tanks, called treated or product water, is discharged into a receiving stream.

The lead adsorbers are backwashed on a daily scheduled basis or when the pressure drop across the carbon beds becomes excessive. The adsorber to be backwashed is taken offstream and washed with secondary effluent drawn from the surge tank. Conventional backwash methods are utilized consisting of initial surface agitation by surface spray and an upflow wash rate of 17 gpm/ft^2 to provide 30% bed expansion. Backwash cycle time per adsorber requires 45 minutes.

The system contains six adsorber tanks, only four of which are required on stream at any time. One of the spare adsorbers, filled with activated carbon, is ready to go on stream; the other spare adsorber is empty.

When the adsorption capacity of the carbon in one of the lead adsorbers is exhausted, the lead adsorber is taken off stream, the adsorber tank in the guard position is switched to the lead position and the spare vessel filled with carbon is brought on stream in the guard position.

The spent carbon contained in the absorber tank taken off stream is removed from the tank in slurry form and transported to the regeneration furnace at a controlled rate of 705 lb of carbon per hour. After passing through the regeneration furnace, the reactivated carbon is transported in slurry form to the spare empty vessel. This regeneration of 315,800 lb of carbon contained in one adsorber tank will require 18.5 days of continuous operation of the regeneration system.

The adsorber containing the carbon to be regenerated is kept filled with water during the period of carbon withdrawal, to minimize carbon bridging across the outlet. Tangential flow nozzles, installed in the conical section of the vessel, can be used to agitate the carbon if bridging occurs.

The spent carbon slurry is dewatered on a stationary screen, the carbon passing into the furnace inlet, while the free water is collected in a sump and returned to the primary clarifiers in the secondary treatment plant.

The vent gas from the furnace is passed through a wet scrubber to reduce particulate emissions to a level acceptable to local air pollution control requirements. The slurry from the scrubber is collected in the same sump as the water from the stationary screen.

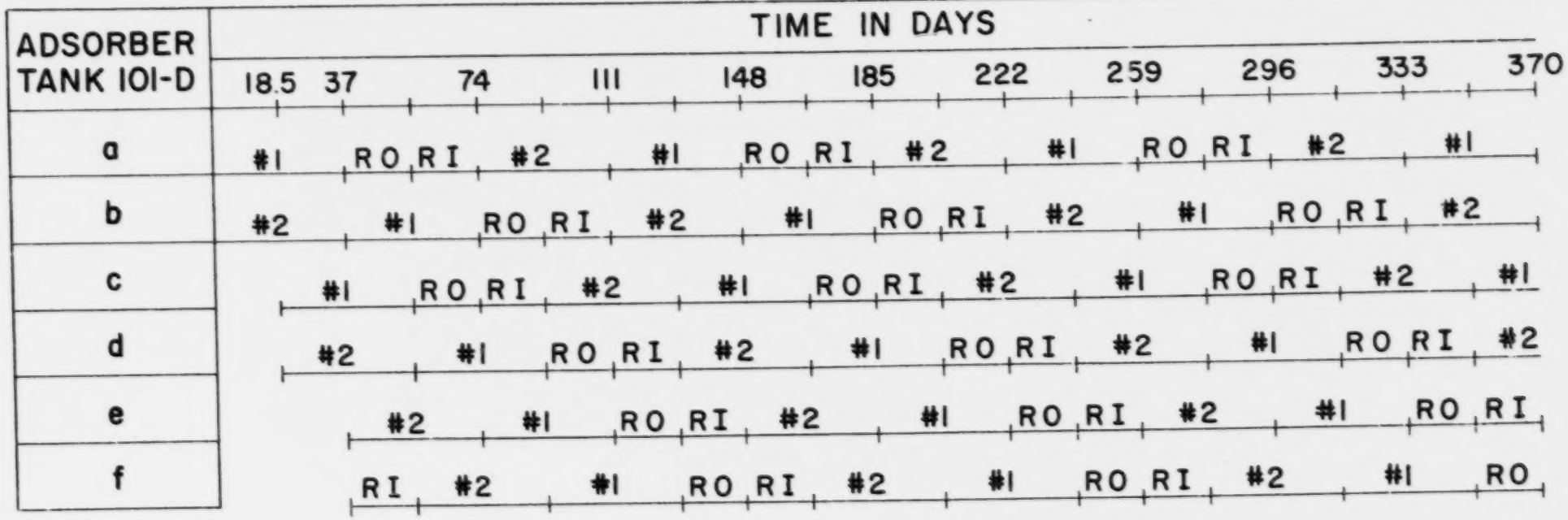
The hot regenerated carbon is discharged under water into a quench tank from which it is transported to the spare vessel. During carbon transfer, the spare vessel is kept filled with water to reduce attrition of the carbon by minimizing the height of fall of the carbon into the vessel.

Make-up carbon is transferred by slurry from the fresh carbon storage tank to the spare vessel to replace any carbon losses. The spare vessel is filled to a fixed height which represents 315,800 lb of carbon.

The start-up of the carbon adsorption system should be on a staggered basis, so that only one lead adsorber tank at a time requires regeneration. This permits the blending of a product water of below-specified quality from one train with a product water of above specified quality from the other train, thereby increasing the allowable COD loading on the carbon between regeneration periods.

The projected operating sequence for all six adsorber tanks is shown in Table I.

TABLE I
ADSORBER OPERATING SEQUENCE


ADSORBER TANK 101-D
TIME IN DAYS
18.5
37
74
111
148
185
222
259
296
333
370
a
#1 RO RI #2 #1 RO RI #2 #1 RO RI #2 #1
b
#2 #1 RO RI #2 #1 RO RI #2 #1 RO RI #2
c
#1 RO RI #2 #1 RO RI #2 #1 RO RI #2 #1
d
#2 #1 RO RI #2 #1 RO RI #2 #1 RO RI #2
e
#2 #1 RO RI #2 #1 RO RI #2 #1 RO RI
f
RI #2 #1 RO RI #2 #1 RO RI #2 #1 RO

SYMBOLS:
- #1 = LEAD ADSORBER IN TRAIN
- #2 = GUARD ADSORBER IN TRAIN
- RO = CARBON OUT FOR REGENERATION
- RI = CARBON IN FROM REGENERATION

DESIGN BASES

The bases used for the conceptual design of the granular activated carbon plant for treating municipal waste water were developed jointly by the contractor's representatives and staff members of the Federal Water Pollution Control Administration's Robert A. Taft Water Research Center, Cincinnati, Ohio. These bases are a result of the preliminary economic evaluation work, the literature review (Report No. TWRC-11, Phases I and II)[1] and field trips to existing plants.

The reader should note that these design bases may not necessarily result in a completely optimized plant. The principal criteria underlying these bases are that this plant design is reasonably well supported by pilot plant data and that the design offers reliability and operability. Design of the recommended system is based on presently available data. There are other systems (such as gravity-flow) which appear to offer considerable economic advantage, but a design of such a system would not be on as firm an experimental basis.

The reader is cautioned not to apply these design bases to the treatment of other waste waters until after bench scale testing of the quality of the waste water has been completed.

The bases for the recommended plant design are as follows:

Water Quality - It is assumed that the feed water has the same characteristics as the water from the secondary treatment plant at Pomona, California. The Chemical Oxygen Demand (COD) concentration to the activated carbon adsorption process is assumed to be 60 mg/l. Suspended solids comprise about 30% of the total COD with the remainder being dissolved COD.

Plant Size - A plant capable of treating 10 million gallons per day (10-MGD) of waste water was chosen because 10-MGD represents the sewage rate from cities of about 100,000 to 300,000 population.

Surge Capacity - A surge basin will be provided to equalize variations in feed rate. The flow rate is assumed to vary sinusoidally between 50% and 150% of the average flow rate over a period of one day. A surge basin was found to be significantly less expensive than adding extra vessels to handle the surge.

Vessel System - A two-stage, packed-bed, downflow system was selected. The packed-bed, downflow adsorber was chosen because most of the pilot plant data were taken on this type of contactor. A two-stage contactor rather than one, three or four stages was chosen because this is an optimum system with respect to capital and operating costs. The relationship between number of stages and carbon loading has not been

determined; however, the economic study did show that the loading in a 3- or 4-stage contactor could not be increased sufficiently to offset the additional capital charges for three or four stages. The single-stage system yields about the same costs as the 2-stage system exclusive of costs associated with carbon regeneration; however, when loading is considered, the costs for the single-stage system will be higher than for a two-stage system.

Carbon Particle Size - The recommendation for an 8 x 30 mesh carbon, rather than 12 x 40 mesh carbon, is based on the results of the economic evaluation of the design variables (Report TWRC-11). If the larger particle size increases the required contact time from 41 minutes (Pomona with 16 x 40 mesh carbon) to 50 minutes but reduces the regeneration loss from 10% to 5%, then the 8 x 30 mesh carbon is less expensive. If the particle size affects neither the required contact time nor the regeneration loss, then the larger particle size yields lower costs because the cost per pound is slightly lower and the carbon bed pressure drop is lower. If the larger particle size increases the required contact time but does not affect the regeneration loss, then there is no significant difference in costs for the two particle sizes. The larger particle size would still be chosen for this case since both experimental data and economic studies indicate potential advantage to use of the larger particle size.

Velocity - The superficial linear velocity (based on empty column area) of the water moving through the carbon bed is taken at 10 gpm/ft^2. Economic studies have shown that there is no significant difference in costs between cases at 7 and 10 gpm/ft^2 all other things being equal. The case at 4 gpm/ft^2, however, yielded much higher costs than either 7 or 10 gpm/ft^2 due to increased vessel costs. If higher velocities require less contact time to effect the same degree of COD reduction then the 10 gpm/ft^2 velocity would be chosen due to lower costs associated with the carbon inventory. But this dependence of contact time on velocity is not supported by the bulk of the data.[1]

Contact Time - The required contact time to reduce the COD from 60 to 7 mg/l is chosen to be 50 minutes (based on empty column volume). This is longer than the 41 minute contact time at Pomona but that operation did not always produce a 7 mg/l COD effluent between regenerations. A longer contact time is conservative and is consistent with higher feed concentrations and with the use of a larger particle size.

Carbon Bed Dimensions - The bed depth-to-diameter ratio (L/D) was determined by a combination of the plant capacity of 10 MGD, a two-stage contactor system, a liquid velocity of 10 gpm/ft^2, a contact time of 50 minutes and an "idle" carbon inventory below 20% of the total carbon. The resulting L/D, greater than one, will assure good contacting during adsorption and backwash. The Pittsburgh Activated Carbon Company[2] recommends an L/D ratio of two.

"Idle" Carbon Inventory - The portion of the total carbon inventory which must be in residence in the system for the purpose of carrying out regeneration without upsetting the normal operation of the adsorption train is referred to as "idle" carbon. The amount of "idle" carbon required for regeneration purposes has been taken as equal to the amount in one vessel. Our study determined that the economics are not affected significantly after the "idle" carbon inventory is reduced below 20% of the total carbon inventory. This, then, indicates that there should be at least two trains of vessels for the two-stage system assuming the plant capacity is above 5 MGD.

Backwash Rate - The backwash rate for the 8 x 30 mesh carbon is 17 gpm/ft^2 so that a 30% bed expansion is achieved during backwash. This is the bed expansion employed at Pomona. Backwashing of the lead contactor is assumed to occur once a day, as at Pomona, using 5% of the daily output from the secondary plant. Bed expansion during backwashing is taken from Cooper and Hager.[3]

Pressure Drop - For the purpose of feed-pumping sizing, a 50 psi pressure drop is assumed to be developed before backwashing is required. This is approximately the same as at Pomona even though the particle size at Pomona is smaller (16 x 40 mesh vs. 8 x 30 mesh). The major portion of the bed pressure drop is contributed by the suspended solids accumulated on the top layer of carbon. This pressure drop will not change much over this particle size range since the void fraction for 12 x 40 mesh is 0.38 and for 8 x 30 mesh is 0.36 which are not significantly different. A spare is included for each pump.

"Spare" Vessels - Two extra vessels are added to the number of vessels which are on stream in the adsorption train. These two "spare" vessels are required for the operation of the regeneration system to store the "idle" carbon which is ready to be and has been regenerated.

Regeneration Rate - Regeneration of the spent carbon is assumed to occur continuously in a multiple-hearth, Herreschoff-type furnace. The regeneration rate is set by the material balance around the plant and an assumed carbon loading of 0.26 lb COD/lb carbon. This loading corresponds to one-half the loading at Pomona after the carbon has been regenerated several times. This assumes that the loading for the two-stage system will be one-half the loading obtained in the four-stage system at Pomona. (Publisher's Note: No data are available to determine what the loading would be on a two-stage system but the assumption of 0.26 lb COD/lb carbon-1700 lb carbon/10^6 gallons - is believed to be conservative. The economic effect of carbon loading can be seen in TWRC 11, Table 16). The regeneration of vessels is assumed to occur on a staggered basis so that all of the lead adsorbers do not have to be regenerated at the same time. Staggering of regeneration in a multi-trained system presents the possibility of blending product water which is less than and better than specified quality. This allows the carbon to be more heavily loaded than in a single-train system thus reducing the regeneration rate.

Carbon Transport - The spent carbon is transported between the vessel and the furnace area as a carbon-water slurry. Then the slurry is drained by a stationary screen. Dewatering studies at Lake Tahoe indicate that a moisture content of 45% can be achieved after 10 minutes drain time while only 40% moisture can be reached after one day. Because of the two "spare" vessels and the feasibility of carbon dewatering in an inclined conveyor or screen, there is no need for elevated dewatering bins.

The carbon slurry transport system design is based on recommendations of the Pittsburgh Activated Carbon Company.[4] Their recommendations are:

1. Minimum linear velocity of 3 feet per second to prevent carbon settling.

2. A carbon-to-water ratio of one pound carbon per gallon of water.

3. Pipeline pressure drop as shown in Figure 4 of the reference.[4]

Transportation of the make-up carbon into the storage tank can be accomplished pneumatically if the carbon vendor's trucks are so equipped. Otherwise, the receiving facility must provide a means for transferring the fresh carbon from the ground to the top of the carbon storage tank. Based upon a delivery requirement of one truck load of carbon (9 tons) per three weeks, a bucket elevator has been selected as the most economical means of conveyance.

Regeneration Furnace - Continuous regeneration of the spent carbon occurs in a multiple-hearth, Herreschoff-type furnace. The furnace is sized on the recommendation from B-S-P Corporation of 100 pounds of carbon regenerated per day per square foot of hearth area. The furnace will be slightly oversized so that regeneration can be carried out at above the average regeneration rate. This will assist in providing smooth operation when the time comes for switching from one vessel to another for regeneration. Air pollution control equipment is provided to prevent odors and particulates from escaping in the flue gas stream.

Regeneration Fuel - The total fuel requirement for the regeneration system is estimated to be 4250 Btu per pound of carbon regenerated. This figure is based on the following recommendations:

1. A B-S-P recommendation of 3000 Btu/lb carbon for furnace heat which is confirmed by Pomona operating data.

2. Lake Tahoe data indicate that 1250 Btu/lb carbon for steam generation of one pound steam per pound carbon is sufficient for satisfactory carbon regeneration.

Carbon Loss - The carbon loss in regeneration is assumed to be 5%, which is the same as that experienced at Tahoe with 8 x 30 mesh carbon. Storage facilities are provided for a three-month supply of make-up carbon.

PLANT DESIGN

The 10-million-gallon-per-day plant (Figure 2, Appendix C) occupies 20,000 square feet of ground. The highest point of the tankage and pipes is 70 feet above ground.

Estimates of material costs are based upon extending all pipe and other service lines to five feet beyond the battery limits of the 200 feet by 100 feet area.

The plant area, less the surge tank, is enclosed with an eight-foot high cyclone fence. Pedestrian and vehicular entrances are provided in the fence. The vehicular entrance is provided to facilitate delivery of equipment and supplies to the plant. Normal yard lighting is provided to illuminate the fenced area during evening operations.

The foundation design for the tankage and equipment is based on a nominal soil bearing capacity of 3000 psf. The concrete foundation slab varies in thickness from 6 inches under the control room to 24 inches under the adsorber tanks. The heavy motors and pumps require foundations of up to 6 cubic yards of concrete.

The base for the surge tank consists of a 95-foot-diameter foundation wall below ground and encircling a 24-inch deep bed of compacted sand.

The 18-foot by 30-foot control room is constructed of concrete block with cement slab floor and metal roof. Communication between the control room and selected parts of the plant is to be by sound powered telephone.

Access to the top and to inspection levels for all tankage and equipment is provided by access ladders. All walkways are constructed of metal grating and enclosed with safety railings.

Conventional materials of construction are used in all instances, as described in the equipment specifications, with the exception of the rubber lining in the adsorber vessels and the polyethelene coated pipe for that portion of the surface wash system contained within the adsorber.

PLANT OPERATION AND CONTROL RATIONALE

The piping, pumps, equipment, and vessels shown on Figure 3 of Appendix C have been designed and selected for the operation of a 10-million-gallon-per-day activated carbon tertiary treatment plant. Control of the plant is maintained by combined manual and electro-pneumatic remote operation as shown on the Control Diagram, Figure 4 of Appendix C.

The heart of the operation of the plant, the control room, contains a control panel for the regeneration system, a graphic control panel with 30 point annunciator alarms and two motor control panels, one for 440-volt requirements and the other for 4160-volt requirements.

The panel alarm system is provided to alert the operator of the malfunction of critical equipment. The alarm points displayed on the panel represent the following indications.

Alarm Points		Indication
1.	Level in Surge Tank 106-F	Hi
2.	Level in Surge Tank 106-F	Lo
3.	Level in Fresh Carbon Storage Tank 101-F	Hi
4.	Level in Fresh Carbon Storage Tank 101-F	Lo
5.	Zeolite Water Softener 107-L	Spent
6.	Steam Generator Pressure 105-U	Lo
7.	Air Compressor Pressure	Lo
8.	Backwash has operated for set time	Complete
9.	Turbidity Meter - Product Water	Hi
10.	Turbidity Meter - Backwash Waste Water	Lo
11.	Differential Pressure Adsorber 101-Da	Hi
12.	Differential Pressure Adsorber 101-Db	Hi
13.	Differential Pressure Adsorber 101-Dc	Hi
14.	Differential Pressure Adsorber 101-Dd	Hi
15.	Differential Pressure Adsorber 101-De	Hi
16.	Differential Pressure Adsorber 101-Df	Hi
17.	Carbon Level in Adsorber 101-Da	Hi
18.	Carbon Level in Adsorber 101-Db	Hi
19.	Carbon Level in Adsorber 101-Dc	Hi
20.	Carbon Level in Adsorber 101-Dc	Hi
21.	Carbon Level in Adsorber 101-De	Hi
22.	Carbon Level in Adsorber 101-Df	Hi
23.	Influent Water Pump 101-Ja & 101-Jb	Off
24.	Feed Water Pump 103-Ja & 103-Jb	Off
25.	Spent Carbon Slurry Pump 104-Ja/Jf	Off
26.	Regenerated Carbon Slurry Pump 110-J	Off
27.	Fresh Carbon Slurry Pump 105-J	Off
28.	Steam Generator Combustion Air Fan	Off
29.	Carbon fines Slurry Pump 112-J	Off
30.	Bucket Elevator 108-F	Off

Normal Operation

Water from the secondary treatment plant enters the 1.6-million-gallon surge tank (106-F) on Figure 3 of Appendix C. The level of the water in the tank is monitored by measuring the hydrostatic pressure in the tank. High and low level warnings are transmitted to the graphic control panel. Overflow from the tank is returned to the secondary treatment plant.

Waste water is withdrawn from the surge tank by feed pump (101-J), pumped through the 20-inch-diameter primary header and distributed through 14-inch-diameter feed lines to individual carbon adsorber vessels. Control of the 3575 gpm flow to each of the two (2) first stage adsorbers is maintained by automatic flow rate controllers activating air operated valves (FV-1) in each feed line. Manually operated gate valves and check valves assure positive shutoff of flow in the feed line and prevent flow reversal during backwash operations.

After passing through the carbon bed, the waste water is discharged through one of eight outlets. Each outlet, 8 inches in diameter, is covered with a 40 mesh stainless steel well point type screen which prevents the carbon from leaving the vessel. The eight water outlets are connected by a 12-inch-diameter pipe shaped to form a ring manifold. The manifold discharges the partially treated waste water through valve (FV-4) into the 20-inch-diameter secondary header.

The flow of partially treated waste water from the secondary header through the 14-inch transfer lines to each of the two second-stage adsorbers is controlled by air-operated valves (FV-3).

The treated waste water flows from the second stage adsorber through air operated valve (FV-5) into a tertiary header. The tertiary header discharges the product water to a receiving stream. The product water is monitored by turbidity meter to indicate any radical changes in the physical characteristics of the discharge.

Adsorber performance is monitored by collected and analyzing samples of both the inflow and outflow of each adsorber. Sampling taps are provided on the feed line into each adsorber and on the discharge manifold at the exit of each adsorber. Chemical and biological analyses of these samples provide a means of recording the performance and organic loading applied to each vessel. The results of this monitoring provides the basis for determining when the carbon in an adsorber requires regeneration.

Backwash Cycle

The lead adsorbers are to be backwashed on a daily basis. Alternatively, backwash may be provided on a demand basis as indicated by excessive pressure drop across the first-stage adsorber and/or as required due to penetration of the carbon beds by a breakthrough of turbidity exceeding established product water quality requirements.

Differential pressure switches, used to detect and indicate pressure drops across the lead adsorbers in excess of 50 psi, sound an alarm at the graphic control panel to alert the operator of the requirement to backwash. The turbidity meter monitoring the product water quality, also serves to warn the operator of the backwash requirement.

The backwash system is designed with the capacity to wash the adsorbers one at a time. The wash water is withdrawn from the surge tank by backwash pump (102-J) and transferred into the 8-inch-diameter surface wash header and into the 12-inch-diameter backwash header. Air operated valve (FV-7) provides remote on and off operation of the surface spray system for each adsorber. The backwash rate to the adsorbers is controlled by flow controller (FV-2) and the adsorber to be backwashed is selected by operating the appropriate valve (FV-20). The backwash water is introduced through the normal treated water outlets in the bottom of the adsorber.

During the backwash cycle, the waste wash water leaves the top of the vessel and flows through valve (FV-6) to a 24-inch-diameter line which returns the water to the primary settling units of the secondary treatment plant.

A turbidity meter monitoring the waste wash water flow is used to detect a reduction of suspended solids contained in the water, thus signifying completion of required backwash. The meter can also be used to indicate if the backwash rate is too high, by measuring increased turbidity caused by a high concentration of carbon in the discharge.

Carbon Transport

The transport of activated carbon within the plant is based upon the use of a hydraulic slurry containing 1 lb of carbon per gallon of water at a minimum velocity of 3 feet per second. Higher velocities and/or leaner slurry mixes are used when criteria other than hydraulic transport take precedence.

Piping for transporting the slurry contains only long radius elbows and plug-type valves to minimize wear due to the highly abrasive characteristics of the carbon.

Existing installations have used eductors to mix and transport the carbon-water slurry. These installations did not have data available to confirm either the hydraulic slurry transport velocities or the carbon-water ratios of the slurry. Attempts were made at Pomona to collect useful data pertaining to the hydraulic transport of the carbon/water slurry in a four-inch pipeline supplied by an eductor. The data collected over a short period of time was scattered and meaningless.

In the current design it is necessary to transport carbon from the adsorbers through the regeneration system to the spare vessel during a continuous period of 18.5 days. No intermediate storage tank is provided to equalize the rate of carbon fed to the furnace. Positive control of

the hydraulic slurry transport must be maintained. Therefore, a 6-inch rotary valve (102-M) was selected to maintain effective control of the rate of discharge of the spent carbon from the adsorber. During normal adsorption operation, loss of carbon through the rotary valve is prevented by an air operated plug valve (FV-21).

The spent carbon is discharged into sump (102-F) which is hydraulically agitated to maintain the carbon in suspension. Flow of water into the sump is regulated by an electro-pneumatic level controller using flow control valve (FV-12). The carbon slurry is withdrawn from the sump and pumped (104-J) through a 1-inch-diameter line to the stationary dewatering screen (108-L).

During withdrawal of the spent carbon, the water in the adsorber is maintained at a fixed level by a level controller (FV-16). Make-up water to maintain this level is drawn from the primary header through a 3/4-inch line. If keeping the carbon in the adsorber submerged during withdrawal fails to prevent bridging of the carbon across the outlet, then supplementary agitation of the carbon in the conical bottom of the tank can be provided by discharging water through 2-inch tangential nozzles installed in the base of the vessel. These nozzles are supplied with water drawn from the backwash header and controlled by remotely operated valve (FV-9).

The reactivated carbon is discharged from the regeneration furnace through a submerged outlet into quench tank (103-F). The flow of water into the tank is regulated by an electro-pneumatic level controller and flow control valve (FV-13). The carbon slurry is withdrawn from the tank and transferred to the empty spare adsorber vessel through a 1½-inch line by pump (110-J). The lower carbon to water ratio in this line is necessary to permit adequate dissipation of the heat contained in the regenerated carbon at temperatures below the boiling point of water.

The three-month supply of carbon stored in the fresh carbon storage tank (101-F) is drawn upon either during regeneration and/or immediately thereafter to assure that the spare vessel receiving the regenerated carbon is filled with a fixed amount of carbon. The carbon level detector system in the adsorber is used to determine when the spare vessel has been filled with the required amount of carbon.

The fresh carbon is withdrawn from the fresh carbon storage tank by a vibra-screw feeder (102-V) and delivered into the hydraulically agitated sump tank (105-F). The carbon is transported in slurry form from this point to the spare vessel. Overflow from the spare vessel is wasted to the primary settling tanks.

The fresh carbon storage tank is instrumented with a weighing system. The changes in weight of the storage tank serve as the basis for ordering new carbon deliveries and for determining the carbon attrition loss per operating cycle.

The carbon to be regenerated flows by gravity from the curved stationary screen into the multiple hearth furnace (101-L) at a design rate of 705 lb/hr. An approximate residence time of 30 minutes is provided in the furnace to evaporate the moisture from the carbon, raise the temperature of the carbon to the reactivation temperature and to effect regeneration of the carbon. Required temperatures are maintained on selected hearth levels through thermocouple control of the gas flow rate to the burners.

Supplementary equipment required to support the operation of the furnace include a combustion air fan (107-J), cooling fan (108-J), induced draft fan and an exhaust gas cleaner (103-L). For this size furnace, odors and particulate matter contained in the exhaust gas are best removed from the exhaust gas by a wet-type scrubber.

Utilities

A potable water source of ten gallons per minute is required to produce 705 lb of steam per hour used in the multiple hearth furnace to assist in the reactivation of the spent carbon. To minimize fouling problems the water is pre-treated by a zeolite water softener (107-L) prior to being heated in the steam generator (105-U).

Natural gas supplied by public utilities serves as fuel for both the multiple hearth furnace and the steam generator. Two-stage reduction is provided to decrease the gas pressure in the distribution lines from 100 psi to a working pressure of 10 psi.

Air supplied by compressor (111-J) is required to operate air-activated valves and for instrumentation control in the electro-pneumatic control system of the facility.

COST ESTIMATE

General

The estimated cost for the design and construction of the 10-million-gallon-per-day activated carbon treatment plant is based on the following criteria:

1. The plant shall be designed, procured and constructed by one major or general contractor having overall responsibility.

2. The geographical location of the plant is the Gulf Coast area for the purpose of establishing environmental conditions, labor costs and freight shipment rates.

3. The prices of materials, equipment and labor are as of March 1969.

4. The 1969 City Cost Index for this location is 85.5

Cost Summary

Materials & Freight	$ 401,863
In place Subcontract (a)	950,040
Insurance	4,600
Field Administration (Prime Contractor) (a)	22,500
Construction Force (b)	160,570
Field Office & Other Field Expense (c)	2,200
Home Office (d)	75,000
Estimated Base Cost	$1,616,733
Contingency	34,142
Plant Investment (PI)	$1,650,875
Carbon @ 26¢/lb	410,544
Fixed Capital Investment (FCI)	$2,061,419

(a) The costs of the prime contractor in providing field supervision and field services for subcontractors are included in the subcontract costs.

(b) Includes wages, fringe benefits, payroll assessment, and tools for construction force.

(c) Costs incurred by the General Contractor to operate his field office.

(d) Includes the cost of home office construction, home office procurement and home office engineering.

This cost summary reflects the results of determining the cost per installed item at the plant site. The summation of costs leading to this summary is organized in a rational manner subtotaling all costs for similar items or equipment under one group such as the total installation cost for all pumps under Group J. The cost per group, which includes appropriate material cost, freight costs, fabricating costs, subcontract costs and labor costs, is set forth as follows:

DESCRIPTION	GROUP	COST
Earthwork, formwork, reinforcement, concrete paving, fencing and foundations	A	$ 42,000
Carbon Adsorber Tanks, including rubber lining and well screens	D	670,740
Non-pressurized slurry tanks, pump sumps, quench tanks, air receivers, surge tank and fresh carbon storage tank	F	103,882
Structural Steel, metal grating, handrails and stairs	H	20,900
Pumps and compressors	J	65,032
Office Building, 18 x 30 concrete block	K	5,400
Regeneration system (8'6"-6 hearth furnace, cooling fan, induced draft fan, combustion air fan, wet type scrubber, control panel), water softener, dewatering screen and instrument air dryer.	L	128,237
Valves & Piping	M	268,994
Electrical Equipment (a)	N	77,851
Instrumentation	O	110,411
Paint for Structural Steel & Pipes	P	3,717
Utility equipment, steam generator	U	5,946
Conveying equipment, vibrating screen and bucket elevator	V	9,362

(a) This estimate does not include either a primary or secondary substation. It is assumed that power will be available at the 4160 volt level.

Operating Costs, ¢/M Gal.

A.	Make-up Carbon @ 26¢/lb	2.20	
	Power @ 1¢/kwh	1.36	
	Backwash Water @ 6¢/M gal	0.32	
	Fuel Gas @ 25¢/MM Btu	0.19	
	Labor @ $3.50/man-hour	1.05	
	Subtotal		5.12
B.	Overhead @ 50% Labor + 1.485% PI/yr	1.20	
	Amortization @ 7.4% FCI/yr (20 yrs @ 4%)	4.18	
	Maintenance @ 5.75% PI/yr	2.60	
	Insurance @ 1% FCI/yr	0.56	
	Subtotal		8.54
	Total Operating Cost		13.66

The total operating cost for the 10-million-gallon-per-day tertiary treatment plant has been divided into two categories:

A. Those costs which are based on fixed requirements.
B. Those costs which are affected by policy decisions.

Category B, representing Overhead, Amortization, Maintenance and Insurance, will vary from one facility to the next. At some installations maintenance costs are not identified as such and at other installations, Insurance protection is not provided. The basis for the development of these costs are contained in Appendix A of the Phase II Report, TWRC-11.

Operating Cost Reductions

The operating cost of make-up carbon is based on a 5% regeneration loss and a maximum loading of 0.26 lb COD/lb C. The cost may be reduced by:

1. Using a cheaper carbon
2. Reducing regeneration loss
3. Increasing organic loading of carbon

Electrical power costs are primarily pumping costs. These could be drastically reduced by operating a gravity flow system.

Backwash water costs will actually be a function of the quantity and frequency of backwashing that is required. Since these factors depend upon the quality of the secondary treatment plant effluent to be treated, no meaningful cost reductions are anticipated.

Fuel gas costs, although a very small contribution to the total operating costs, could be reduced through the use of a more efficient regeneration system. At least one-half of the residence time of the carbon in the furnace is utilized to evaporate moisture from the carbon particles.

Labor costs cannot be appreciably reduced.

Of the fixed operating costs listed, the make-up carbon and the electrical power costs offer the most incentive for further reduction. The other fixed operating costs are of lesser significance or are more resistant to being reduced.

If the operating cost for this process is compared to the cost of an alternative tertiary treatment process, it should be compared on the same bases, both as to type and degree of treatment provided and the rates applied to various operations. For this reason, the total operating cost for the 10-million-gallon-per-day carbon treatment plant should be listed as 5.12¢/M gal plus appropriate charges for administrative, maintenance and financial costs.

RECOMMENDATIONS

The data presently available are sufficient to optimize partially the design of granular carbon adsorption of waste water. Particular deficiencies in the data to permit total process optimization may be eliminated by conducting investigations to determine the functional relationships of specific design variables.

1. Determine the effect of particle size at long contact times on the adsorption rate and the adsorption capacity of the carbon.

2. Determine the effect of repeated regeneration cycles on the adsorption rate, adsorption capacity and particle size of the carbon.

3. Given the results of 1 and 2, effect optimization studies to minimize regeneration costs.

4. Determine the effect of velocity in the 1-10 gpm/ft^2 range on COD removal efficiency as a function of contact time.

5. Conduct an extended side-by-side comparison of upflow and downflow process schemes to confirm the relative effectiveness of each in removal of COD.

6. Determine the optimum size of a water surge tank as a function of flow and concentration of contaminants at the site in question.

7. Develop testing procedures for obtaining data to evaluate the raw water characteristics that affect the values of the process design parameters for carbon adsorption.

8. Determine the reaction kinetics of biological activity within a carbon adsorption column that effects removal of organic contaminants.

9. Given the results of 8, determine the physical values of the process parameters for both biological and chemical adsorption phenomena effecting reduction of organic contaminants in a carbon column.

The bare operation cost of the 10 million-gallon-per-day carbon treatment plant has been placed at 5.12¢/M gal. Further reduction in this cost is dependent upon improved process design incorporating the results of the investigations recommended above. Definite economies can be effected by:

1. Improving the regeneration process
2. Increasing the carbon capacity
3. Decreasing carbon costs
4. Utilizing gravity-flow systems

The total operating cost of any municipal plant includes the costs for amortization, overhead, supervision and insurance. The assignment of these costs, all or in part against a particular plant operation, is a judgment or policy type decision on the part of management and as such is not influenced by engineering design. Therefore, the operating cost of a 10-million-gallon-per-day treatment plant will be more than 5.12¢/M gal. but should be less than 13.66¢/M gal.

References

1. Cover, A. E. and Pieroni, L. J. "Appraisal of Carbon Contacting: Phase I, Evaluation of the Literature on the Use of Granular Activated Carbon for Tertiary Waste Water Treatment and Phase II, Economic Effect of Design Variables," Taft Water Research Center Report No. TWRC-11, May 1969.

2. "Basic Design Techniques," Pittsburgh Activated Carbon Company.

3. Cooper, J. C. and Hager, D. G., " Water Reclamation with Activated Carbon," Chem. Engr. Progr., 62 (10) 87 (October 1966).

4. "Column Operating Procedures with Pittsburgh Granular Activated Carbon," Pittsburgh Activated Carbon Company, February 1967.

5. "Building Construction Cost Data," 27th Annual Edition, Robert Snow Means Company, Inc., Duxbury, Massachusetts, p. 124.

APPENDIX A

EQUIPMENT LIST

Equipment List - 10 Million Gallon Capacity
Carbon Adsorption Tertiary Waste Water Treatment Plant

No. of Units	Item	Description
		Tankage and Drums
6	101-D	Carbon Adsorption tank, 315,800 lb of dry 8 x 30 mesh activated carbon.
1	101-F	Fresh carbon storage tank, 77,400 lb of dry 8 x 30 mesh carbon.
6	102-F	Spent carbon slurry tank.
1	103-F	Carbon quench tank.
1	105-F	Fresh carbon transfer pump sump.
1	106-F	Surge tank, 1,600,000 gallons of water capacity.
1	107-F	Air receiver (included with Item 111-J).
1	108-F	Pump sump for wet scrubber (Item 103-L) centrate and stationary screen (Item 108-L) filtrate.
		Pumps, Compressors and Fans
2	101-J	Influent pump - 7800 gpm motor driven, centrifugal type 18" x 14".
2	102-J	Backwash pump - 6500 gpm, motor driven, centrifugal type 16" x 12".
2	103-J	Feed water pump for slurry tanks - 100 gpm motor driven, centrifugal type, 3" x 1½".
6	104-J	Spent carbon slurry pump - 20 gpm motor driven, centrifugal type, 1½" x 1¼".
1	105-J	Fresh carbon slurry pump - 50 gpm, motor driven, centrifugal type, 2½" x 2".

EQUIPMENT LIST (Cont'd.)

No. of Units	Item	Description
		Pumps, Compressors and Fans (Cont'd.)
2	106-J	Boiler feed water pump - 10 gpm, motor driven, centrifugal type, 1½" x 1½".
1	107-J	Combustion air fan (included with Item 101-L).
1	108-J	Cooling fan (included with Item 101-L).
1	109-J	Induced draft fan (included with Item 101-L).
1	110-J	Regenerated carbon slurry pump - 50 gpm, motor driven, centrifugal type, 2½" x 2".
1	111-J	Air Compressor - 100 cfm @ 100 psi.
1	112-J	Slurry pump for wet scrubber centrate and screen filtrate - 25 gpm, motor driven, centrifugal type, 1½" x 1¼".
		Special Equipment
1	101-L	Carbon regeneration system.
1	103-L	Wet scrubber (included with Item 101-L).
1	107-L	Zeolite water softener.
1	108-L	Stationary Dewatering Screen.
1	109-L	Instrument Air Dryer.
		Piping
N/A	101-M	Consists of piping and supports for varying lengths of 3/4" to 30" steel pipe, epoxy coated steel pipe 1½" diameter to 8" diameter and required valves and fittings.
6	102-M	Rotary valve - 6", motor operated
48	104-M	Water outlet and backwash inlet assembly with stainless steel 40 mesh screen. (8 required for each Item 101-D.)
32	106-M	Tangential jet assemblies. (4 required for each Item 101-D.)

EQUIPMENT LIST (Cont'd.)

No. of Units	Item	Description
		Electrical Equipment
1	101-N	Main Control Panel.
115		Indicator lights
59		Push-button - 2 unit
1		30 point annunciator
N/A	102-N	Locally Mounted Equipment
6		Magnetic starter
6		½ H.P. rotary valve
50		Solenoid valve
7		Pressure switch
12		Pneumatic switch
9		Capacitance probe
4		Load cells
17		Other 110 volt connections
9		Co-AX cable sets
-		3/c #12 cable
-		Incandescant lighting
-		Grounding
1	103-N	Motor Control Center (440 volt)
1		Incoming breaker
1		Incoming compartment
1		Transformer 4160/440-150 KVA
1		Transformer compartment
1		Transformer 1, 440/110 volt
1		Distribution Panel, 110 volt, 12 circuit
17		Starters for items 103-J, 104-J, 106-J, 107-J, 108-J, 109-J, 110-J, 111-J
1	104-N	Motor Control Center (4160 volts)
1		Incoming breaker
1		Incoming section
		Starters-full voltage non-reversing for Items 101-J and 102-J
8		Indicator lights
4		AC Power bus
4		Ground bus
1		Cable entrance
1		Transition Compartment

EQUIPMENT LIST (Cont'd.)

No. of Units	Item	Description
		Electrical Equipment (cont'd.)
1		Surge protection
3		Potheads
1		Isolating switch
4		Key interlock
1	101-0	Instrumentation and Control
6		Butterfly control valve, 8"
6		Butterfly control valve, 10"
12		Butterfly control valve, 12"
18		Butterfly control valve, 14"
12		Globe control valve, size 3/4", national pipe thread (npt)
2		Globe control valve, size 1½" - 150 lb flanged
6		Globe control valve, size 2" - 150 lb flanged
12		Ball control valve, size 1½" - 150 lb flanged
3		Gas Pressure reducing valve, size 3/4" npt, self-operated
8		Signal converter, MA to 3-15 lb
12		Orifice plate, size 14"
25		Differential pressure transmitter, ½" npt connections, 3-15 lb output
6		Differential pressure transmitter, with 4" tank side mounting flange
6		Indicating pneumatic controller
9		Capacitance level controller with level probes in pump tanks
2		Turbidity analyzer including sample pump - ½" npt - 3/4" npt connections
2		Signal converter, mv to ma
1		Weigh system, electronic, with 4 load cells under fresh carbon tank, one scale cabinet

EQUIPMENT LIST (Cont'd.)

No. of Units	Item	Description
		Electrical Equipment (Cont'd.)
7		Pressure switch
12		Purge meters, ¼" npt connections
50		Electric solenoid - valves, ¼" npt
84		Pressure gages, miscellaneous
24		3 valve manifolds, ½" npt
1		Control and graphic display panel, pre-piped and wired, two sections (84" x 48" x 18" and 84" x 48" x 24")
		Not included under 101-0 - motor control center, field mounted magnetic starters, rotary motor driven valves, controls for package steam boiler, manual valves, wire and tubing.
		Paint and Insulation
150	101-P	Paint, gallons for piping and exposed steel.
		Utility Equipment
1	105-U	Steam generator - packaged type, - gas fired, 705 lb/hr steam @ 10 psig
		Conveying Equipment
1	102-V	Vibra-screw feeder, motor driven, variable speed 2" diameter screw, vibrating hopper.
1	103-V	Bucket elevator - continuous buckets, 10-ton per hour capacity, 60' maximum.

APPENDIX B

EQUIPMENT SPECIFICATIONS

General

These specifications outline the functions and requirements for the major equipment items shown on Figures 2 and 3 of Appendix C.

1.0 Carbon Adsorption Tanks, Item No. 101-D

1.1 Each tank shall have a capacity of 315,800 lb of dry 8 x 30 mesh activated carbon having a bulk density of 25.0 lb per cu. ft in addition to approximately 500,000 lb of water.

1.2 Tanks shall be of welded construction and fabricated from carbon steel plate and be designed for a pressure of 130 lb per sq. inch in addition to the quantities of carbon and water stated above. Tanks shall be designed per latest ASME Code.

1.3 The tanks shall have a 21'-0" inside diameter x 43'-6" high cylindrical section with a 45° conical bottom 10'-6" high.

1.4 Tanks shall be designed for mounting on structural steel legs.

1.5 Ellipsoidal head shall be provided with two (2) inspection manholes and one (1) 14" diameter vertical flanged nozzle.

1.6 Tanks shall be lined with hard rubber laminated sheet.

1.7 Tank shell shall have one (1) 8" diameter flanged nozzle and one (1) 1½" diameter flanged nozzle located 5'-0" below tangent line of shell and roof.

1.8 Conical section shall have the following:

1.8.1 Four (4) 2" diameter flanged nozzles arranged horizontally.

1.8.3 One (1) 6" diameter flanged nozzle at bottom of section for discharge into a flanged rotary valve supplied by others.

1.9 The tanks shall be painted on the outside with one shop coat of primer and two field coats of standard Alkyd.

2.0 Fresh Carbon Storage Tank, Item No. 101-F

2.1 The tank shall have a capacity of 77,400 lb of dry 8 x 30 mesh activated carbon having a bulk density of 25.0 lb per cu. ft. Carbon shall be delivered to tank by a bucket elevator conveying system.

2.2 The tank shall be of welded construction and fabricated from carbon steel plate. Tanks shall be designed per latest ASME Code.

2.3 The tank shall have 12'-0" inside diameter x 31'-0" high cylindrical section with a 45° conical bottom 6'-0" high.

2.4 The tank shall be designed for mounting on structural steel legs.

2.5 Roof shall be self-supporting type of water tight construction.

2.6 Tank shell shall have one (1) 12" diameter flanged nozzle.

2.7 The tank shall be painted with one shop coat of primer and be painted with two field coats of epoxy, inside and standard Alkyd, outside.

3.0 Spent Carbon Slurry Tank, Item No. 102-F

3.1 Each tank shall be designed to contain a mixture of carbon and water.

3.2 Tanks shall be of welded construction and fabricated from carbon steel plate.

3.3 Tanks shall have open top and consist of a 2'-6" inside diameter x 4'-0" high cylindrical section with a 60° conical bottom.

3.4 Bottom of conical section shall have a 2" flanged nozzle.

3.5 Tanks shall be designed for mounting on structural steel legs.

3.6 The tank shall be painted with one shop coat of primer and be painted with two field coats of epoxy, inside and standard Alkyd, outside.

4.0 Carbon Quench Tank, Item 103-F

4.1 Tank shall be designed to contain a mixture of carbon and water.

4.2 Tank shall be of welded construction and fabricated from carbon steel plate.

4.0 Carbon Quench Tank, Item 103-F (Cont'd.)

4.3 Tank shall have open top and consist of a 4'-0" inside diameter x 4'-0" high cylindrical section with a 60° conical bottom.

4.4 Bottom of conical section shall have a 1½" flanged nozzle.

4.5 Tank shall be designed for mounting on structural steel legs.

4.6 The tank shall be painted with one shop coat of primer and be painted with two coats of epoxy, inside and standard Alkyd, outside.

5.0 Fresh Carbon Transfer Pump Sump, Item 105-F

5.1 Sump shall be designed to contain a mixture of 8 x 30 mesh activated carbon having a bulk density of 25.0 lb per cu. ft and water.

5.2 Sump shall be of welded construction and fabricated from carbon steel plate.

5.3 Sump shall have open top and consist of a 4'-0" inside diameter x 4'-0" high cylindrical section with a 60° conical bottom.

5.4 Bottom of conical section shall have a 2" diameter flanged nozzle.

5.5 Cylindrical section shall have one (1) 1½" diameter flanged nozzle.

5.6 Tank shall be designed for mounting on structural steel legs.

5.7 The tank shall be painted with one shop coat of primer and be painted with two field coats of epoxy, inside and standard Alkyd, outside.

6.0 Surge Tank, Item No. 106-F

6.1 Tank shall have a capacity of 1,600,000 gallons of treated waste water.

6.2 Tank shall be of welded construction and fabricated from carbon steel plate.

6.3 Tank shall be of cylindrical shape 85'-0" inside diameter x 40'-0" high.

6.4 Tank shell shall have one (1) 30" diameter flanged outlet located 36" above bottom of shell.

6.0 Surge Tank, Item No. 106-F (Cont'd.)

6.5 Tank shall be located on grade.

6.6 Tank shall be supplied with outside ladder of welded steel construction anchored to tank shell and equipped with safety cage.

6.7 Bottom of tank shall be sloped with center drain.

6.8 The tank shall be painted with one shop coat of primer and be painted with two field coats of epoxy, inside and standard Alkyd, outside.

7.0 Pump Sump for Wet Scrubber and Stationary Screen, Item 108-F

7.1 Sump shall be designed to contain a mixture of activated carbon fines and waste combustion products collected as the centrate from the wet scrubber (item No. 103-L) and a combination of water and activated carbon fines collected as the filtrate passing through the stationary screen (item No. 108-L).

7.2 Sump shall be of welded construction and fabricated from carbon steel plate.

7.3 Sump shall have open stop and consist of a 4'-0" inside diameter x 4'-0" high cylindrical section with a 60° conical bottom.

7.4 Bottom of the conical section shall have a 1½" diameter flanged nozzle.

7.5 Tank shall be designed for mounting on structural steel legs.

7.6 The tank shall be painted with one shop coat of primer and be painted with two field coats of epoxy, inside and standard Alkyd, outside.

8.0 Influent Pump; Item No. 101-J

8.1 Each pump shall be designed to handle 7800 gpm of water at 270 foot head.

8.2 Pumps shall have 18" flooded suction and 14" discharge and be of the horizontal centrifugal type with axial split cast iron case.

8.3 Pumps shall include but not necessarily be limited to the following:

8.3.1 Bronze impeller

8.3.2 Bronze wear rings

8.0 Influent Pump, Item No. 101-J (Cont'd.)

8.3 (Continued)

8.3.3 Steel shaft

8.3.4 Grease lubricated ball bearings.

8.3.5 Packed type stuffing boxes.

8.4 Each pump shall be complete with motor. Pump and motor shall be mounted on a common base and be direct connected by a rigid coupling.

8.5 Pump and motor shall be for outdoor service.

9.0 Backwash Pumps, Item No. 102-J

9.1 Each pump shall be designed to handle 6500 gpm of water at 200 foot head.

9.2 Pumps shall have 16" flooded suction and 12" discharge and be of the horizontal centrifugal type with axial split cast iron case.

9.3 Pumps shall include but not necessarily be limited to the following:

9.3.1 Bronze impellar

9.3.2 Bronze wear rings

9.3.3 Steel shaft

9.3.4 Grease lubricated ball bearings

9.3.5 Packed type stuffing boxes

9.4 Each pump shall be complete with motor. Pump and motor shall be mounted on a common base and be directly connected by a rigid coupling.

9.5 Pump and motor shall be for outdoor service.

10.0 Feed Water Pumps, Item No. 103-J

10.1 Each pump shall be designed to handle 100 gpm of water at 80 foot head.

10.0 Feed Water Pumps, Item No. 103-J (Cont'd.)

10.2 Pumps shall have 3" flooded suction and 1½" discharge and be of the horizontal centrifugal type with axial split cast iron case.

10.3 Pumps shall include but not necessarily be limited to the following:

10.3.1 Bronze impeller

10.3.2 Bronze wear rings

10.3.3 Steel shaft

10.3.4 Grease lubricated ball bearings

10.3.5 Packed type stuffing boxes

10.4 Each pump shall be complete with motor. Pump and motor shall be mounted on a common base and be directly connected by a flexible coupling.

10.5 Pump and motor shall be for outdoor service

11.0 Spent Carbon Slurry Pumps, Item No. 104-J

11.1 Each pump shall be designed to handle 20 gpm of spent carbon slurry (Sp. Gr. 1.05) at 75 foot head.

11.2 Pumps shall have 1½" flooded suction and 1¼" discharge and be of the centrifugal type with split cast iron case.

11.3 Pumps shall include but not necessarily be limited to the following:

11.3.1 Abrasion resistant rubber lined casing.

11.3.2 Abrasion resistant rubber coated impeller.

11.3.3 Anti-friction ball bearings.

11.4 Each pump shall be complete with motor and variable diameter sheave "V" belt drive. Pump and motor shall be mounted on a common base.

11.5 Pump and motor shall be for outdoor service.

12.0 Fresh Carbon Slurry Pump, Item 105-J

12.1 Pump shall be designed to handle 50 gpm of fresh carbon slurry (Sp. Gr. 1.05) at 100 foot head.

12.0 Fresh Carbon Slurry Pump, Item 105-J (Cont'd.)

12.2 Pump shall have 2½" flooded suction and 2" discharge and be of the centrifugal type with split cast iron case

12.3 Pump shall include but not necessarily be limited to the following:

12.3.1 Abrasion resistant rubber lined casing.

12.3.2 Abrasion resistant rubber coated impellar.

12.3.3 Anti-friction ball bearings.

12.4 Each pump shall be complete with motor and variable diameter sheave "V" belt drive. Pump and motor shall be mounted on a common base.

12.5 Pump and motor shall be for outdoor service.

13.0 Boiler Feed Water Pumps, Item No. 106-J

13.1 Each pump shall be designed to handle 10 gpm of water at 80 foot head.

13.2 Pumps shall have 1½" end suction and 1½" discharge and be of the close coupled centrifugal type with cast iron case.

13.3 Pumps shall be bronze fitted.

13.4 Each pump shall be complete with motor. Pump and motor shall be mounted on a common base and be close coupled.

13.5 Pump and motor shall be for outdoor service.

14.0 Regenerated Carbon Slurry Pump, Item 110-J

14.1 Pump shall be designed to handle 50 gpm of regenerated carbon slurry (Sp. Gr. 1.05) at 100 foot head.

14.2 Pump shall have 2½" flooded suction and 2" discharge and be of the centrifugal type with split cast iron case.

14.3 Pump shall include but not necessarily be limited to the following:

14.3.1 Abrasion resistant rubber lined casing.

14.3.2 Abrasion resistant rubber coated impeller.

14.0 Regenerated Carbon Slurry Pump, Item 110-J (Cont'd.)

14.3 (Continued)

14.3.3 Anti-friction ball bearings.

14.4 Each pump shall be complete with motor and variable diameter sheave "V" belt drive. Pump and motor shall be mounted on a common base.

14.5 Pump and motor shall be for outdoor service.

15.0 Air Compressor, Item 111-J

15.1 Compressor shall be designed to deliver 100 cfm at 100 psi.

15.2 Compressor shall be of the reciprocating type.

15.3 Compressor shall be complete with motor, regulators, instrumentation, control panels, silencers, all integral piping and wiring.

15.4 Compressor and motor shall be mounted on a common base.

16.0 Carbon Regeneration System, Item 101-L

16.1 Regeneration system shall be designed to regenerate spent 8 x 30 mesh granular activated carbon containing organic contaminants adsorbed from waste water.

16.2 Flow rate shall be 705 lb per hour carbon plus 320 lb per hour water.

16.3 System shall include but not necessarily be limited to the following:

16.3.1 Multiple hearth furnace complete with all casings, fabricated steel, refractories, burners, insulation, motors and drives, feed inlet, product outlet, access doors, platforms railings, ladders, gas outlet with damper and hot air stack.

Size of furnace shall be 8"-6" O.D. x 7"-0" I.D. with six (6) hearths
Rabble arms and teeth shall be fabricated of stainless steel.

Drive for rabble arms shall be by central shaft driven through a cast bevel gear and pinion. The pinion shall be mounted on the output shaft of a variable speed gear reducer driven by an electric motor.

16.0 Carbon Regeneration System, Item 101-L

16.3.1 (Continued)

Burner system shall be for natural gas and shall be complete with all necessary accessories and piping.

Each hearth shall have three (3) 1½" steam inlet nozzles.

16.3.2 Instrument panel with all necessary instruments and controls.

16.3.3 Wet type gas scrubber.

16.3.4 Induced draft fan with drive.

16.3.5 Combustion air fan with drive.

16.3.6 Cooling fan with drive.

17.0 Zeolite Water Softener, Item No. 107-L

17.1 Softener shall be designed for continuous operation and shall be a duplex unit to allow one softener to be locked out while the other unit recharges.

17.2 Supply water conditions are as follows:

Flow	-	10 gpm
Chloride as NaCl	-	60 mg/l
ph	-	7.2
Total hardness as $CaCo_3$	-	100 mg/l
Suspended matter	-	None
Pressure	-	35 psig
Temperature	-	70°F

17.3 Softener shall have provisions for fully automatic operation of cycling and brine system controls.

18.0 Stationary Dewatering Screen, Item No. 108-L

18.1 The screen shall be designed to handle 13 gpm of 8 x 30 mesh activated carbon at 10% solids concentration.

18.2 Screen shall be fabricated of stainless steel.

18.3 Screen shall have integral feed compartment.

18.4 Oversize particle and undersize particle discharges shall be provided.

19.0 Instrument Air Dryer, Item 109-L

19.1 The dryer shall be capable of drying 100 cfm of compressed air at 100 psig. The dew point of dry air discharge shall be -20°F.

19.2 Dryer shall be of the electric regenerative type, complete with all necessary controls.

19.3 Accessories shall include prefilter, afterfilter and trap.

20.0 Steam Generator, Item 101-V

20.1 Steam generator shall be of the packaged type capable of producing 705 lb per hour saturated steam at 10 psig. Generator will be used to supply steam to a carbon regeneration furnace.

20.2 Fuel shall be natural gas with a low heating value of 944 BTU per cu. ft supplied at 10 psig.

20.3 Generator shall include but not necessarily be limited to the following:

20.3.1 Skid base

20.3.2 Insulation and jacket

20.3.3 Forced draft blower and motor with air/fuel switch

20.3.4 Instrument panel

20.3.5 Flame failure control

20.3.6 Steam gauge

20.3.7 Combination water column with low water cutoff and feed pump control switches.

20.3.8 Plain water gage.

20.3.9 Water column blow-down valve

20.3.10 Main "Y" blow-off valve

20.3.11 ASME safety valve

20.3.12 Feed check and stop valve

20.3.13 Blow-off separator

20.0 Steam Generator, Item 101-V (Cont'd.)

20.3.14 Continuous blow-off valve.

20.3.15 Rear observation port with cover.

20.3.16 Automatic feeder for boiler water treatment

20.3.17 Gas pressure regulator.

20.3.18 Motorized gas valve.

20.3.19 Manual shut-off gas cock.

20.3.20 Modulating gas valve.

20.4 Generator shall be designed in accordance with ASME Code.

20.5 All wiring shall be color coded and installed according to National Electric Code.

20.6 Unit shall be self-controlled and furnished with all attached piping and wiring within the assembly.

21.0 Vibra Screw Feeder, Item No. 102-V

21.1 Each feeder shall be designed to handle dry 8 x 30 mesh activated carbon having a bulk density of 25.0 lb per cu. ft.

21.2 Feeders shall consist of a 2" diameter screw with both rotating and vibrating motion and a vibrating hopper.

21.3 Feeders shall be complete with motor and variable speed screw drive.

21.4 Each feeder, motor and drive shall be mounted on a common base.

21.5 Feeders shall be constructed of carbon steel plate.

22.0 Information to be Supplied by Vendors

22.1 Drawings and description of equipment including overall dimensions and materials.

22.2 Total weight of equipment.

23.0 Facilities to be Supplied by Purchaser

23.1 Unloading and storage of equipment

23.2 Installation of equipment if not provided by subcontract agreement.

23.3 Foundations for equipment

23.4 Wiring and piping not integral with equipment

23.5 Necessary utilities

23.6 Externally attached structural members

APPENDIX C - PLANS

CARBON ADS
21.0 I.D.
FIVE VESSELS CONT
ACTIVATED C

NORMAL 7,150 GPM
DESIGN 7,800 GPM
70°F.
1.0 S.G.
1.0 CP.

FEED PUMP
101-Ja, Jb

OVERFLOW

3,575 GPM

106-F
SURGE TANK
1,600,000 GAL.

SECONDARY
EFFLUENT
3.4 TO 10 MGD
6.0 mg/l COD (TOTAL)
4.2 mg/l COD (DISSOLVED)

50 PSIG

101-Da

101-Db

101-Dc

102-Ma

VENT

102-Mb

NORMAL 5,900 GPM
DESIGN 6,500 GPM
(INTERMITTENT)

102-Ja, Jb
BACKWASH PUMP

102-Fa

102-Fb

102-Fc

104-Jc

104-Jb

104-Ja

INDUCED
DRAFT AIR
FAN

103-L
WET
SCRUBBER

101-L
HEAT
REGENERATION
SYSTEM

FURNACE
8'-6" O.D.-6 HEARTH

NATURAL GAS
5.3 SCFM

37.4 SCFM

12 GPM

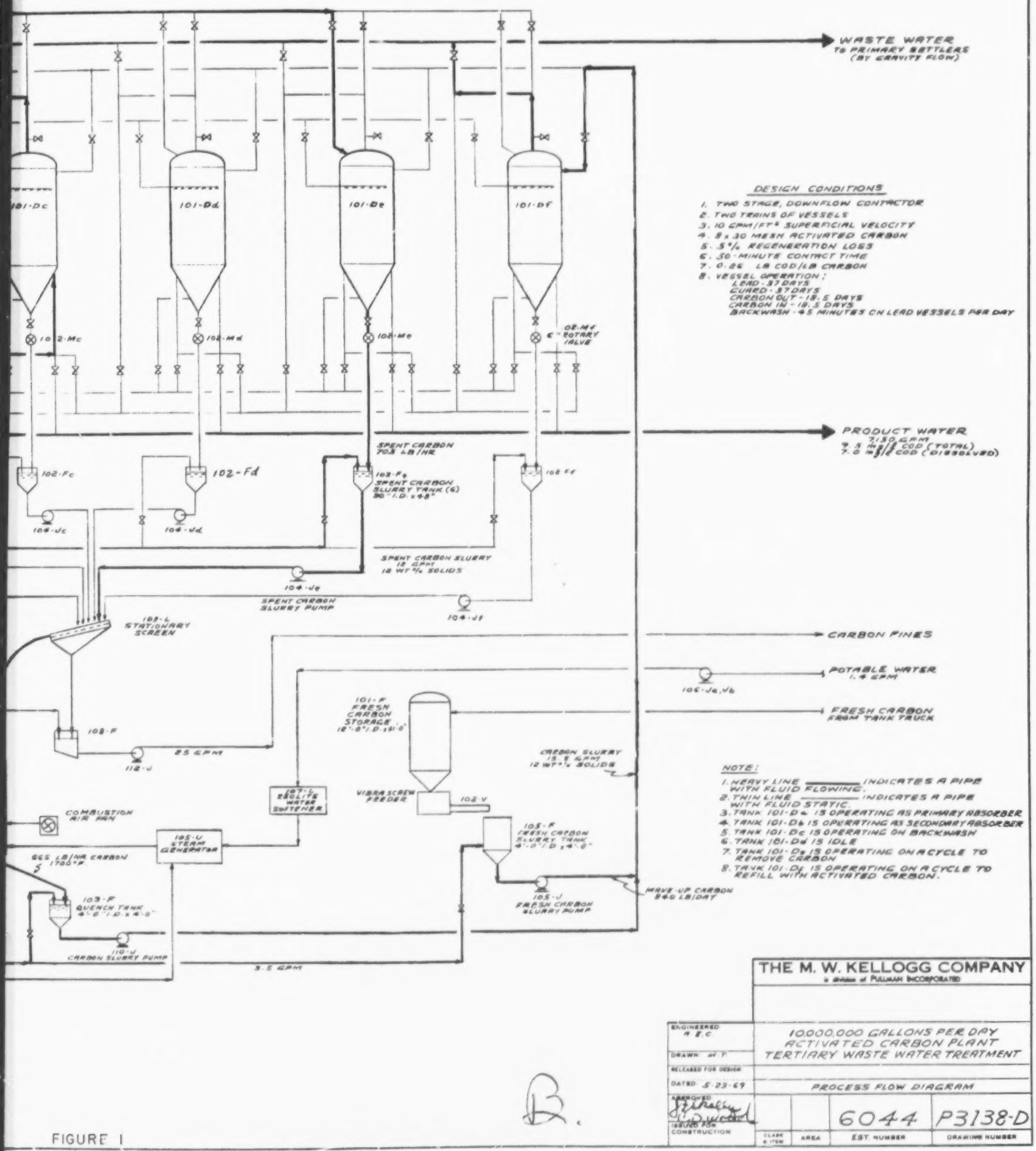
15.5 GPM

COOLING
FAN

103-J, Ja
CARBON SLURRY
WATER PUMP

A1

FIG
C



DESIGN CONDITIONS

1. TWO STAGE, DOWNFLOW CONTACTOR
2. TWO TRAINS OF VESSELS
3. 10 GPM/FT² SUPERFICIAL VELOCITY
4. 8 x 30 MESH ACTIVATED CARBON
5. 5% REGENERATION LOSS
6. 30-MINUTE CONTACT TIME
7. 0.26 LB COD/LB CARBON
8. VESSEL OPERATION:
   LEAD - 37 DAYS
   GUARD - 37 DAYS
   CARBON OUT - 18.5 DAYS
   CARBON IN - 18.5 DAYS
   BACKWASH - 45 MINUTES ON LEAD VESSELS PER DAY

NOTE:

1. HEAVY LINE _____ INDICATES A PIPE WITH FLUID FLOWING.
2. THIN LINE _____ INDICATES A PIPE WITH FLUID STATIC.
3. TANK 101-Da IS OPERATING AS PRIMARY ABSORBER
4. TANK 101-Db IS OPERATING AS SECONDARY ABSORBER
5. TANK 101-Dc IS OPERATING ON BACKWASH
6. TANK 101-Dd IS IDLE
7. TANK 101-Dg IS OPERATING ON A CYCLE TO REMOVE CARBON
8. TANK 101-Df IS OPERATING ON A CYCLE TO REFILL WITH ACTIVATED CARBON.

THE M. W. KELLOGG COMPANY
A Division of PULLMAN INCORPORATED

ENGINEERED A.E.C.	10,000,000 GALLONS PER DAY ACTIVATED CARBON PLANT TERTIARY WASTE WATER TREATMENT
DRAWN M.Y.	
RELEASED FOR DESIGN	
DATED 5-23-69	PROCESS FLOW DIAGRAM
APPROVED	
RELEASED FOR CONSTRUCTION	CLASS & ITEM: — AREA: — EST. NUMBER: 6044 DRAWING NUMBER: P3138-D

FIGURE 1

C-1

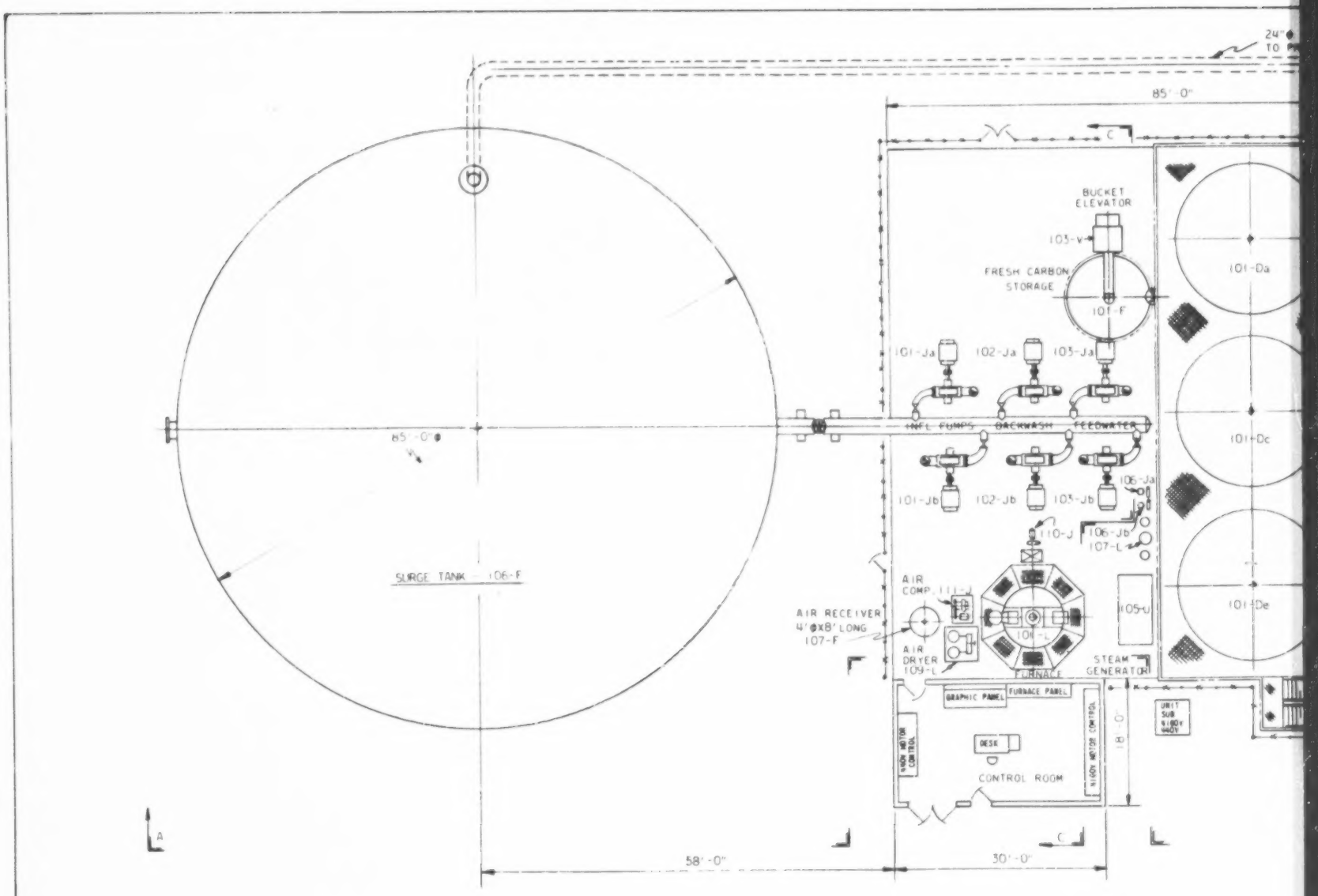
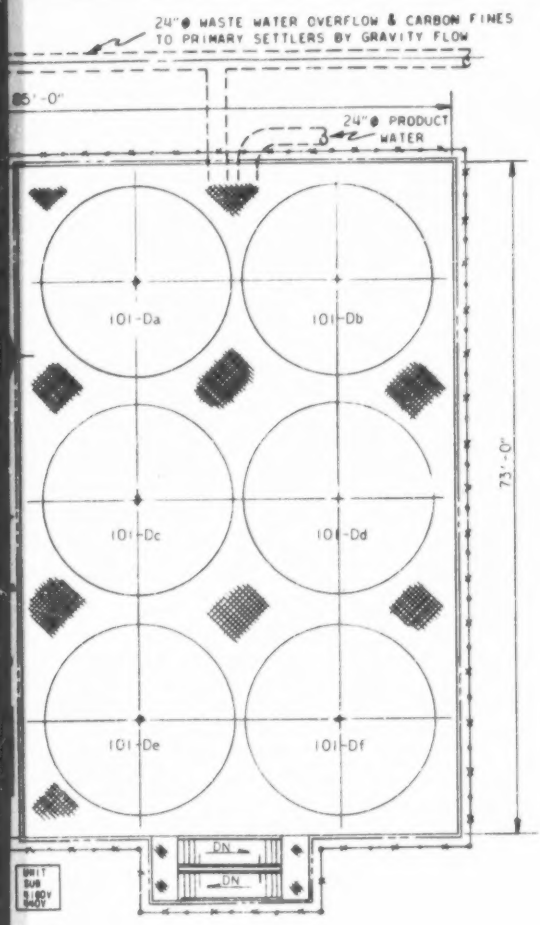
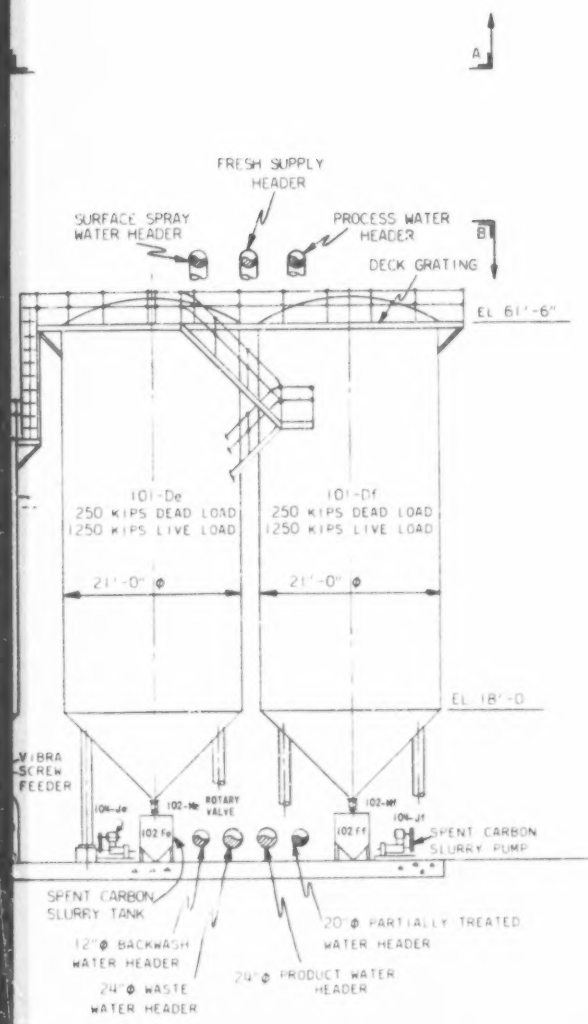
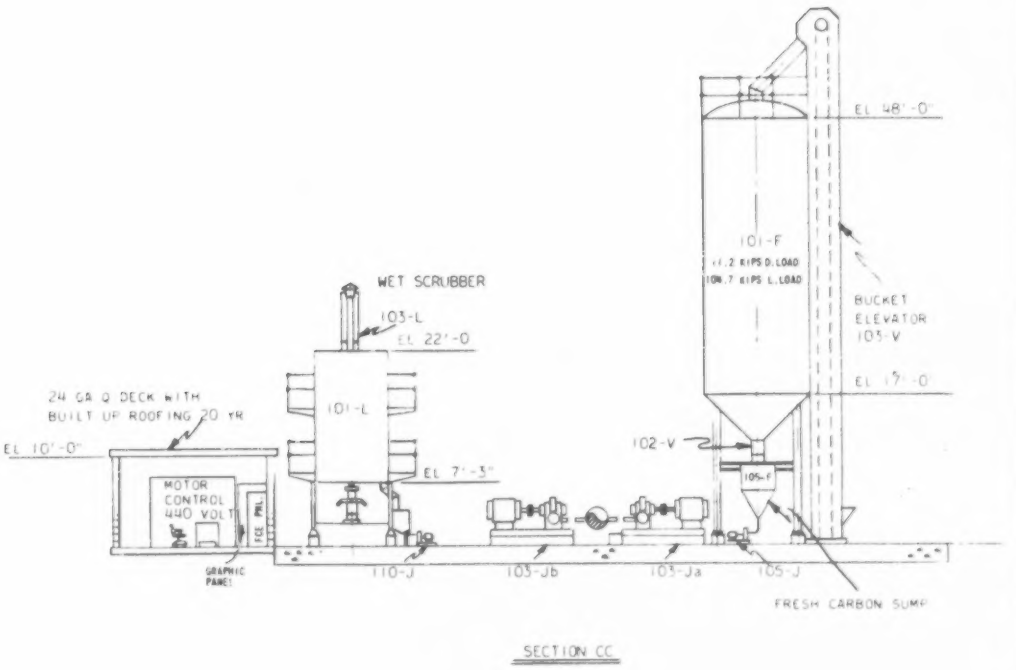

24"Ø TO
85'-0"
BUCKET ELEVATOR
103-V
FRESH CARBON STORAGE
107-F
101-Da
101-Ja
102-Ja
103-Ja
INFL. PUMPS
BACKWASH
FEEDWATER
101-Dc
106-Ja
101-Jb
102-Jb
103-Jb
106-Jb
107-L
110-J
85'-0"Ø
SURGE TANK 106-F
AIR COMP. 111-J
AIR RECEIVER 4'Ø X 8' LONG 107-F
AIR DRYER 109-F
104-L
105-U
101-De
STEAM GENERATOR
FURNACE
GRAPHIC PANEL
FURNACE PANEL
DESK
CONTROL ROOM
480V MOTOR CONTROL
4160V MOTOR CONTROL
30'-0"
UNIT SUB 4160V 480V
58'-0"
30'-0"
SECTION BB
SURFACE SPRAY WATER HEADER
OVERFLOW LEVEL
MAX. OVERFLOW LEVEL
SURGE TANK 106-F
DEWATERING SCREEN
WET SCRUBBER
101-F
108-L
101-De
250 KIPS DEAD L
1250 KIPS LIVE L
21'-0"Ø
101-L
8'-6"Ø
102-V
VIBRA SCREW FEEDER
AIR RECEIVER 107-F
30"Ø
30" INLET NOZZLE
105-U
108-F SUMP PUMP
112-J
SPENT CARBON SLURRY TANK
12"Ø BACKWASH WATER HEADER
24"Ø WASTE WATER HEADER
SECTION A-A

FIGURE 2
C-2







SECTION CC

10 MILLION GAL./DAY
ACTIVATED CARBON PLANT
TERTIARY WASTE WATER TREATMENT
PLAN & ELEVATIONS
Swindell-Dressler Company
A Pullman Incorporated
PITTSBURGH PENNSYLVANIA

FIGURE 2

C-2

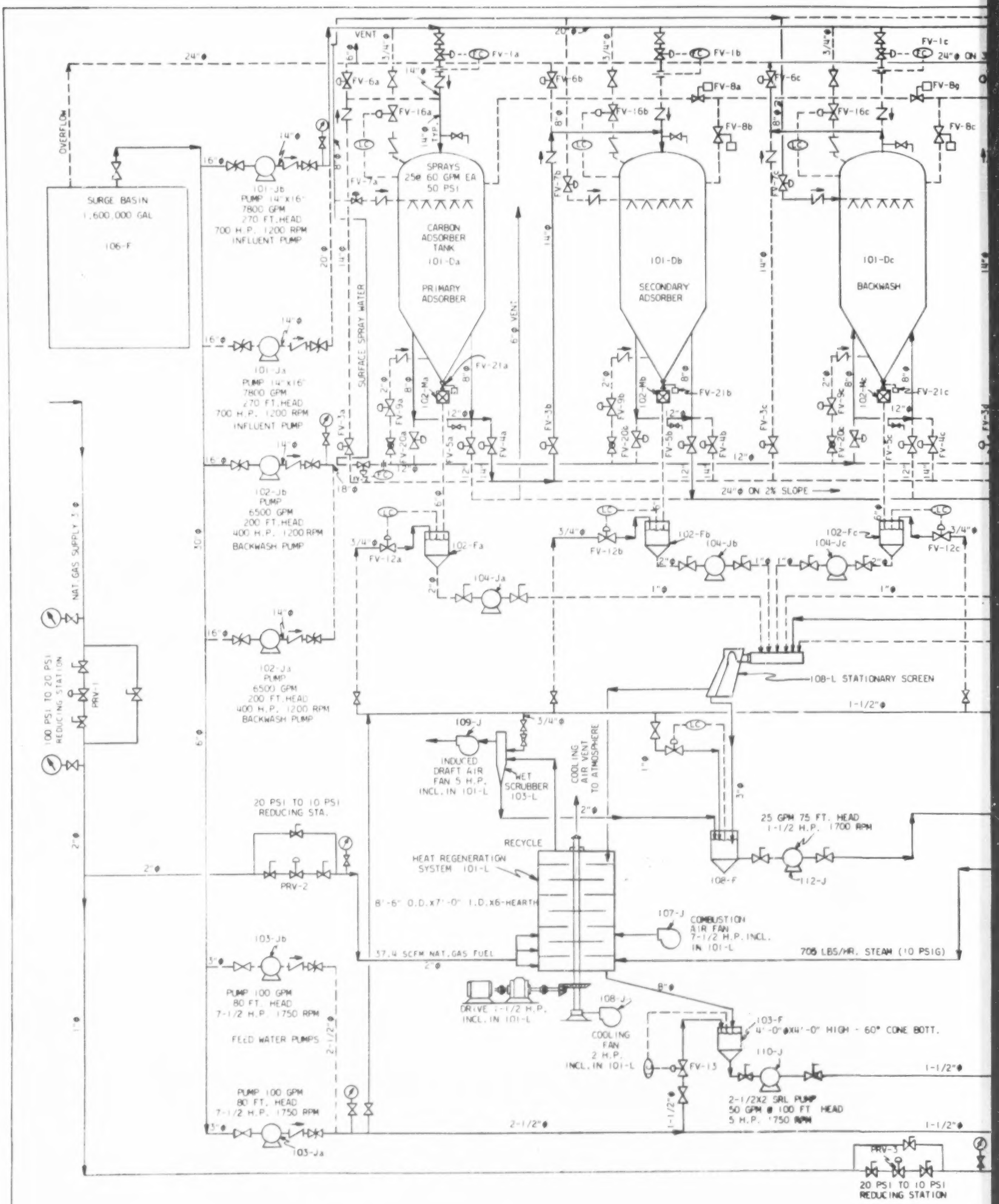
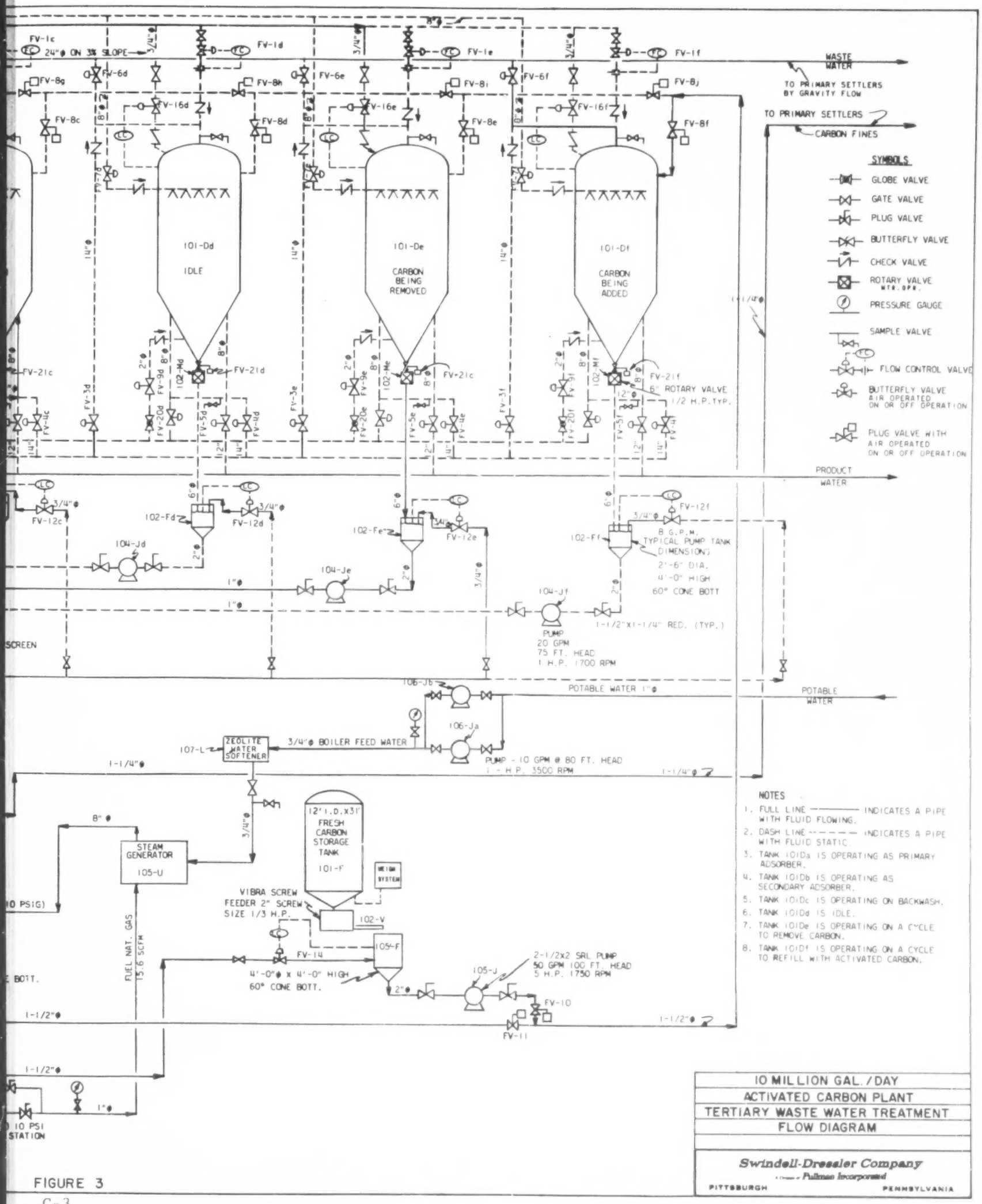

VENT
24"ø
OVERFLOW
SURGE BASIN
1,600,000 GAL
106-F
101-Jb
PUMP 14"X16"
7800 GPM
270 FT. HEAD
700 H.P. 1200 RPM
INFLUENT PUMP
101-Ja
PUMP 14"X16"
7800 GPM
270 FT. HEAD
700 H.P. 1200 RPM
INFLUENT PUMP
102-Jb
PUMP
6500 GPM
200 FT. HEAD
400 H.P. 1200 RPM
BACKWASH PUMP
102-Ja
PUMP
6500 GPM
200 FT. HEAD
400 H.P. 1200 RPM
BACKWASH PUMP
NAT. GAS SUPPLY 3 ø
100 PSI TO 20 PSI
REDUCING STATION
PRV-1
SURFACE SPRAY WATER
SPRAYS
25ø 60 GPM EA
50 PSI
CARBON
ADSORBER
TANK
101-Da
PRIMARY
ADSORBER
101-Db
SECONDARY
ADSORBER
101-Dc
BACKWASH
6"ø VENT
24"ø ON 2% SLOPE
FV-1a
FV-1b
FV-1c
FV-6a
FV-6b
FV-6c
FV-8a
FV-8b
FV-8c
FV-16a
FV-16b
FV-16c
FV-7a
FV-7b
FV-7c
FV-21a
FV-21b
FV-21c
FV-3a
FV-3b
FV-3c
FV-4a
FV-4b
FV-4c
FV-5a
FV-5b
FV-5c
FV-9a
FV-9b
FV-9c
FV-20a
FV-20b
FV-20c
102-Ma
102-Mb
102-Mc
102-Fa
102-Fb
102-Fc
104-Ja
104-Jb
104-Jc
FV-12a
FV-12b
FV-12c
108-L STATIONARY SCREEN
109-J
INDUCED
DRAFT AIR
FAN 5 H.P.
INCL. IN 101-L
WET
SCRUBBER
103-L
COOLING
AIR VENT
TO ATMOSPHERE
20 PSI TO 10 PSI
REDUCING STA.
PRV-2
RECYCLE
HEAT REGENERATION
SYSTEM 101-L
8'-6" O.D.x7'-0" I.D.x6-HEARTH
108-F
112-J
25 GPM 75 FT. HEAD
1-1/2 H.P. 1700 RPM
107-J
COMBUSTION
AIR FAN
7-1/2 H.P. INCL.
IN 101-L
37.4 SCFM NAT. GAS FUEL
705 LBS/HR. STEAM (10 PSIG)
DRIVE 1-1/2 H.P.
INCL. IN 101-L
108-J
COOLING
FAN
2 H.P.
INCL. IN 101-L
103-F
4'-0"øX4'-0" HIGH - 60° CONE BOTT.
110-J
FV-13
2-1/2X2 SRL PUMP
50 GPM @ 100 FT. HEAD
5 H.P. 1750 RPM
103-Jb
PUMP 100 GPM
80 FT. HEAD
7-1/2 H.P. 1750 RPM
FEED WATER PUMPS
PUMP 100 GPM
80 FT. HEAD
7-1/2 H.P. 1750 RPM
103-Ja
PRV-3
20 PSI TO 10 PSI
REDUCING STATION

FIGURE C-3



NOTES

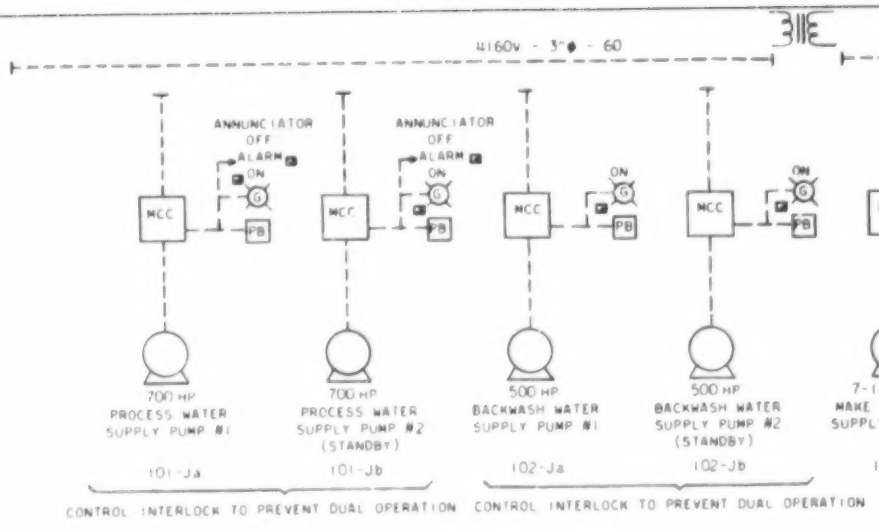
1. FULL LINE ———— INDICATES A PIPE WITH FLUID FLOWING.
2. DASH LINE - - - - - - INDICATES A PIPE WITH FLUID STATIC.
3. TANK 101Da IS OPERATING AS PRIMARY ADSORBER.
4. TANK 101Db IS OPERATING AS SECONDARY ADSORBER.
5. TANK 101Dc IS OPERATING ON BACKWASH.
6. TANK 101Dd IS IDLE.
7. TANK 101De IS OPERATING ON A CYCLE TO REMOVE CARBON.
8. TANK 101Df IS OPERATING ON A CYCLE TO REFILL WITH ACTIVATED CARBON.

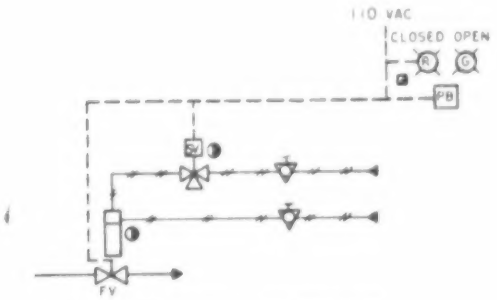
10 MILLION GAL./DAY
ACTIVATED CARBON PLANT
TERTIARY WASTE WATER TREATMENT
FLOW DIAGRAM
Swindell-Dressler Company a Pullman Incorporated
PITTSBURGH PENNSYLVANIA

FIGURE 3

C-3

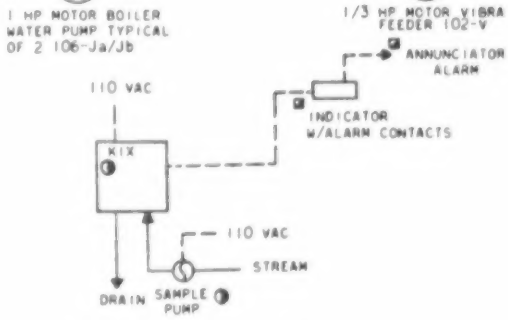
B.





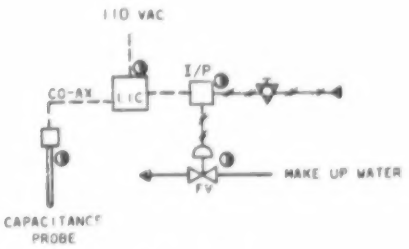
VALVE REMOTE CONTROL - TWO POSITIONS
TYPICAL OF FORTY-EIGHT (48)

1. PROCESS WATER TO ADSORBER TANK - SECONDARY SERVICE
   QUANTITY SIX, VALVE TAG FV-3A/3F.
2. PROCESS WATER FROM ADSORBER TANK - PRIMARY SERVICE
   QUANTITY SIX, VALVE TAG FV-4A/4F.
3. PROCESS WATER FROM ADSORBER TANK - SECONDARY SERVICE
   QUANTITY SIX, VALVE TAG FV-5A/5F.
4. BACKWASH WATER FROM ADSORBER TANK
   QUANTITY SIX, VALVE TAG FV-6A/6F.
5. ADSORBER SURFACE SPRAY WATER - BACKWASH CYCLE
   QUANTITY SIX, VALVE TAG FV-7A/7F.
6. SLURRY TO ADSORBER TANK - CARBON FILL CYCLE
   QUANTITY TEN, VALVE TAG FV-8A/8J.
7. FRESH CARBON SLURRY, FROM PUMP 105-J-CARBON FILL CYCLE
   QUANTITY ONE, VALVE TAG FV-10.
8. REGENERATION CARBON SLURRY FROM PUMP 106-J-CARBON FILL CYCLE
   QUANTITY ONE, VALVE TAG FV-11.
9. BACKWASH WATER TO ADSORBER
   QUANTITY SIX VALVE TAG FV-20a/20f.



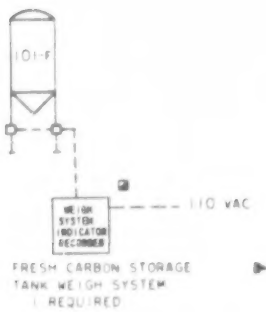
TURBIDITY INDICATION - ALARM
TYPICAL OF TWO

1. PLANT EFFLUENT, TAG K1X-1, ALARM ON HIGH.
2. PLANT BACKWASH RECYCLE, TAG K1X-2, ALARM ON LOW.

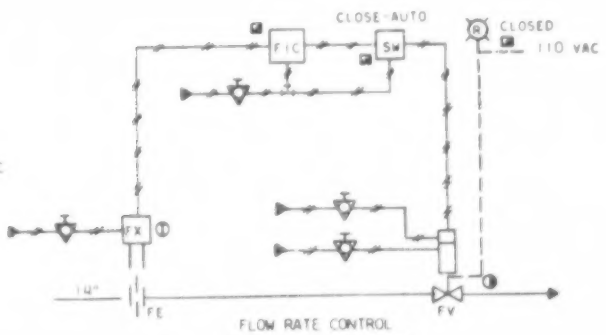


LEVEL CONTROL
TYPICAL OF NINE (9)

1. PUMP TANK - 102-F
   QUANTITY SIX, TAGS LIC-12A/12F,
   FV-12A/12F, ID-12A/12F.
2. PUMP TANK 103-F.
   QUANTITY ONE, TAGS LIC-13, FV-13, I/P-13.
3. PUMP TANK - 105-F.
   QUANTITY ONE, TAGS LIC-14, FV-14, I/P-14.
4. PUMP TANK 108-F
   QUANTITY, ONE TAGS LIC-15, FV-15, I/P-15.

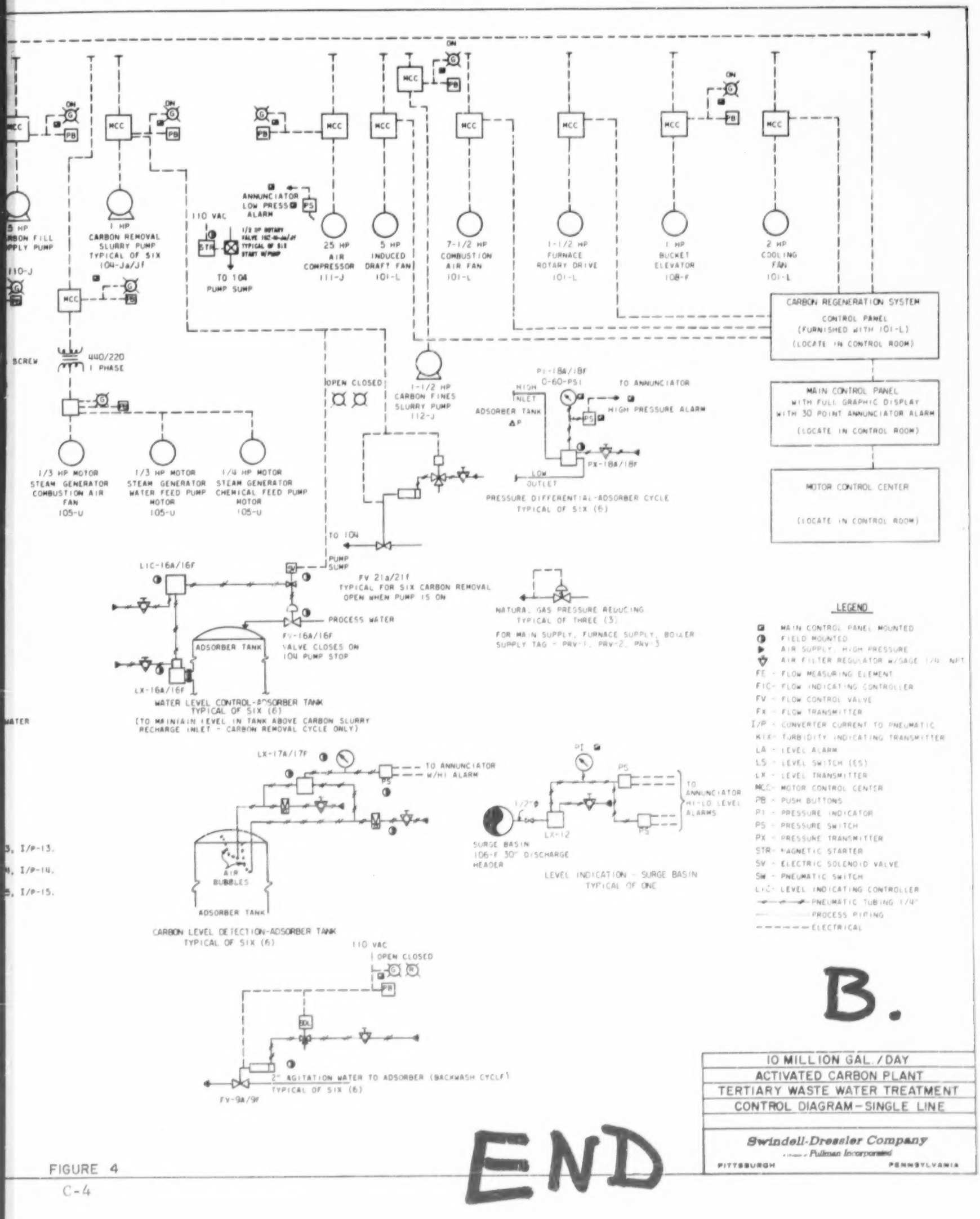


FRESH CARBON STORAGE
TANK WEIGH SYSTEM
1 REQUIRED



FLOW RATE CONTROL
TYPICAL OF SEVEN (7)

1. PROCESS WATER TO ADSORBER TANK - PRIMARY SERVICE
   QUANTITY SIX TAGS FE-1A/1F, FX-1A/1F, FIC-1A/1F, SW-1A/1F, FV-1A/1F.
2. BACKWASH WATER TO ADSORBER TANK
   QUANTITY ONE, TAGS FE-2, FX-2, FIC-2, FV-2, SW-2.



B.

10 MILLION GAL./DAY
ACTIVATED CARBON PLANT
TERTIARY WASTE WATER TREATMENT
CONTROL DIAGRAM - SINGLE LINE
Swindell-Dressler Company
A Pullman Incorporated
PITTSBURGH PENNSYLVANIA

END

FIGURE 4

C-4